The Canadian Entomologist

Vol. LXXXIX Ottawa, Canada, June 1957 No. 6

Deterioration of Fire-Killed Pine in Ontario and the Causal Wood-Boring Beetles[1]

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Introduction

In 1948, the Mississagi region of northern Ontario was swept by a major conflagration that began on May 25 and which, because of dry weather conditions, was not brought under control until July 23. When the fire had been extinguished, it was found to have spread over 27 townships, or 281,388 acres in all. Officers of the Ontario Department of Lands and Forests estimated that approximately 75 per cent of the fire area bore mature stands of eastern white pine (*Pinus strobus* L.), red pine (*P. resinosa* Ait.) and jack pine (*P. banksiana* Lamb.). Salvage operations began immediately in an effort to save this vast amount of valuable timber.

It is well known that even in the hottest forest fire destruction of usable wood is ordinarily prevented by the thickness of the bark and by the moisture in the wood itself. This is particularly true of the thick-barked species. In fire-killed western Douglas fir (*Pseudotsuga taxifolia* (Poir.) Britton) stands, it has been calculated that destruction of merchantable wood amounted to only three or four per cent of the stand volume (Beall *et al.*, 1935). Observations in the Mississagi region indicated similar conditions after fires in eastern pine stands. If, then, all the merchantable timber in a fire-killed stand could be salvaged immediately after the fire, little loss would be incurred. However, except in very small fires, immediate salvage of all timber is usually impossible, and while fire can seldom be held responsible for the destruction or loss in grade of wood, it nevertheless quickly brings about the weakening or death of the trees. Once this occurs the stage is set for the entry of insects and fungi into the wood and its progressive deterioration.

During a forest fire, not all trees suffer the same degree of burn. Depending on time of day, weather conditions, or type and amount of fuel available, fire may creep along the ground, or race through the tree-tops. Thus, some trees are burned only about the roots, others may be scorched along the length of the first log, and still others may be charred from base to tip of crown, with twigs and even small branches consumed. Consequently, trees may be killed outright by the fire, or be damaged in widely differing degrees, which may seriously affect the progress of deterioration in individual trees with different burn histories.

No published information is available concerning the deterioration of pine stands in eastern Canada, but studies conducted elsewhere throw some light on the problem. In fire-killed Douglas fir stands in western Oregon and Washington, Kimmey and Furniss (1943) found that the rapidity of deterioration varied inversely with the size and age of the tree, the thickness of the sapwood, and the width of the growth rings. Deterioration was most rapid in the upper parts of the trees, in young stands, and where populations of wood-boring insects had already built up in dead timber resulting from previous fires. The respective roles of insects and fungi could not be separated.

In fire-killed white spruce (*Picea glauca* (Moench) Voss) in northern Sas-

[1]Contribution No. 349, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada. Based on a portion of a thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy, McGill University, April, 1955.

katchewan, Richmond and Lejeune (1945) were able to relate borer attack to severity of burn. Trees with bark burned thin were found to be immune to attack, while moderately burned trees were attacked first, principally by deep-boring species. Trees in which the cambium was killed by heat, but which were not burned, and trees with injured roots, were attacked last and chiefly by shallow-boring species. It was concluded that it is economically feasible to carry the salvage of fire-killed spruce into the second winter after fire.

In fire-injured ponderosa pine (*Pinus ponderosa* Laws.) in California, Salman (1934) also found that the rate of deterioration was proportional to severity of burn, as exhibited by percentage defoliation and extent of injury to the cambium.

Although he did not study the course of tree deterioration, Trägårdh (1929) found that the degree of infestation of burned pine in Sweden by *Monochamus sutor* L. was proportional to the degree of fire injury. No oviposition was noted in trees with more than half the crown still green by the autumn following an early summer fire. The astonishing abundance of sawyer beetles in the fire area was attributed to attraction of the insects from miles away by the smoke.

The work of Howden and Vogt (1951), who studied insect communities in standing dead pine (*P. virginiana* Mill.) in Maryland during the ten-year period after tree death, is of particular interest. They found that bark beetles were the primary invaders in the dying trees, but after a period of six months relinquished their supremacy to buprestids and cerambycids. In the early stages of deterioration, most of the insects present were those common only to pines. Later, there occurred forms that are found in almost any species of tree in an advanced state of deterioration.

The Mississagi fire provided an opportunity to study deterioration in fire-damaged eastern pine stands. The principal causes of deterioration in fire-killed timber are wood-boring insects and wood-rotting fungi, the latter generally gaining entry through the insect galleries. The study reported here was almost wholly concerned with the insects, the fungi found in the fire-killed pine having been the object of a separate study (Basham, 1956). Since other authors have found a relationship between severity of burn and insect attack, this was investigated. In addition, the species of insects in the burned trees, and their responses to certain influences, were also studied.

Plan of Study

Field studies commenced in the summer of 1949, and continued throughout the summers of 1950 and 1951. Nine stands in the burned-over area were studied. These stands were selected after preliminary aerial and ground reconnaissance of most of the burn, with a view to obtaining information from as representative a portion of the area as possible, and particularly from stands of different forest composition that had not been disturbed by salvage operations.

Examination of Sample Trees

Studies were carried out on eastern white pine, red pine, and jack pine. The trees were selected to obtain representative samples of each species and each of the various degrees of burn. Each sample tree was fully described as to d.b.h. (diameter at breast height), total height, length of crown, and the extent of charring on the trunk and fire-damage in the crown.

After felling, 1-foot sample blocks were cut at 16-foot intervals from each tree, beginning at the base. For each sample block the amount of bark charring was recorded, and any insect attacks in the bark were noted. The bark was then carefully peeled from the block and the circumference recorded. All cerambycid larvae found in the bark or between the bark and the wood were preserved in

70 per cent alcohol for later identification. The number of borer entrance and exit holes on the block surface and the extent of bark beetle attack were recorded. The block was then split, radially, into twelve more or less equal sections, and galleries appearing on the radial faces thus exposed were recorded by depth from the wood surface in one-half inch classes. Finally, each section was split tangentially to recover any larvae in the wood. The holes made by different species were not recorded separately during the summer of 1949, but this was done during the ensuing summers when more knowledge of the habits of the insects had been gained.

Dating Time of Death of Trees Sampled

Since field studies could not be undertaken until the summer following the fire, by which time many of the trees were dead and heavily infested by a variety of insect species, and since it was known that at least some of the species would infest only dead or dying trees, some means of establishing the time of death was essential. It was possible to do this with confidence on the basis of the appearance of the tree and the developmental stage of certain insects within them, particularly of the bark beetle *Ips pini* Say. Trees examined during the summer of 1949 that bore no foliage and contained abandoned *Ips* galleries could safely be said to have died during the summer of 1948. Trees that retained at least some brown foliage and were currently under attack by *Ips* had obviously died during the winter, or, at any rate, after the preceding season's insect activity had ended. All trees examined after 1949 had been marked and described at least a year before examination, so their time of death is positively known.

Collecting and Rearing

The identification of the larvae recovered from the sample blocks was begun during the winter of 1949-50, using the key to North American cerambycid larvae devised by Craighead (1923). Although this key was very useful in making tentative identifications, some of the species encountered in this study were not included in it; therefore, in 1951 adults were collected in the fire area and caged with freshly cut logs of the three species of pine. Mating and oviposition occurred, and thus larvae were obtained that could be related to identified adults.

To facilitate the collecting of adults and to study periods of activity and host tree preferences, 12 white pine and 12 red pine "trap" trees, located close to each other, were felled on June 26, 1951, and examined each day in a uniform manner between 1500 and 1600 hours EDST until August 26. The numbers of each species of cerambycid active on the trees were recorded; then all, or a portion, of the adults were collected for use in the rearing program.

Insects Found in Fire-Killed Pine

The principal insect species found breeding in or at rest on fire-killed pine are given in Table 1. This list does not include the total insect fauna of the fire-killed trees, but is probably complete for the family Cerambycidae, the main object of the study. While bark beetles were often present in very large numbers and permitted the entrance of wood-staining fungi, they nevertheless did no direct damage to the wood. The hymenopterous borers of the family Siricidae were encountered only rarely in the fire area, and the borers of the beetle family Buprestidae were only slightly more common.

The cerambycids found in pine differ greatly in economic importance, owing to differences in life history and in methods of feeding. All, for some period of larval life, are obligate feeders on phloem tissue, and, actually, most species spend

TABLE I

Principal Wood-infesting Insects Found in the Fire Area

Species	Host trees			Larvae found in sample blocks	Found only as adults
	White pine	Red pine	Jack pine		
Order COLEOPTERA					
Family BUPRESTIDAE					
Chrysobothris dentipes Germ.	x	x	x	?[1]	
C. scabripennis Cast. and Gory	x	x		?	
Chalcophora sp.			x		x
Dicerca sp.			x		x
Family PYTHIDAE					
Pytho sp.	x	x	x	x	
Family CERAMBYCIDAE					
Monochamus notatus (Drury)	x	x	x	x	
M. scutellatus (Say)	x	x	x	x	
M. mutator Lec.	x	x	x	?	
Asemum atrum Esch.	x	x		x	
Xylotrechus sagittatus Germ.	x	x		x	
X. undulatus Say	x	x		x	
Tetropium cinnamopterum Kby.	x	x	x	x	
Acmaeops proteus (Kby.)	x	x	x	x	
Acanthocinus pusillus Kby.	x	x	x	x	
Rhagium inquisitor (L.)		x		x	
Arhopalus agrestis Kby.		x			x
Anoplodera chrysocoma (Kby.)					x
A. canadensis Oliv.	x				x
Callidium violaceum (L.)					x
Neoclytus muricatulus (Kby.)					x
Astylopsis sexguttata (Say)					x
Pogonocherus mixtus Hald.	x	x			x
Family CURCULIONIDAE					
Pissodes affinis Rand.	x	x	x	x	
Family SCOLYTIDAE					
Ips pini Say	x	x	x	x	
Order DIPTERA					
Family RHAGIONIDAE					
Xylophagus fasciatus Walk.	x	x	x	x	
Order HYMENOPTERA					
Family SIRICIDAE					
Urocerus albicornis (F.)	x				x
U. cressoni Nort.	x				x

[1]Occurrence probable, but not observed.

the entire larval period under the bark where they do no direct damage to the wood. These may be referred to as shallow-boring species in contrast to the more harmful deep-boring species. The members of the genus *Monochamus*, the principal deep-boring species, were the most important forms in fire-damaged pine from an economic standpoint, the larvae causing the defect known in the lumber trade as "worm holes".

Judging by published records, there are at least 22 species of cerambycids that might attack fire-killed pine in the Mississagi region. Of these, nine were collected from the sample blocks examined, and eight occurred only as adults either in flight in the area, or at rest on trees and logs (Table I). The following

five species were not encountered although they have been reported as breeding in pine: *Leptura subhamata* Rand.; *Typocerus velutinus* (Oliv.); *Evodinus monticola* (Rand.); *Sachalinobia rugipennis* (Swaine and Hopping); and *Pogonocherus penicillatus* Lec.

General Larval Anatomy

The larval anatomy of the cerambycids has been discussed in detail by Craighead (1923) and by Duffy (1953), and will be described only briefly here as an introduction to the key that follows.

Cerambycids can usually be distinguished by form and colour from most of the other larvae found beneath bark or in wood. In form the larvae range from cylindrical to quite depressed. The integument is thin though sometimes of leathery appearance on the prothorax, and is usually white, grey, or pale-testaceous, but never dark. The degree of pubescence varies considerably, but is heaviest on the lateral areas in most species.

The extensible head is usually withdrawn deep into the prothorax; it may be flattened or rounded in cross-section, and, being sclerotized, is usually much darker than the body. The mandibles are short and strong, and may have an oblique or gouge-like cutting edge. The labrum and clypeus are distinct, the latter commonly being hyaline and glabrous. The labium and maxillae are prominent and fleshy. The antennae are very small, and one to several pairs of ocelli are present on the genal areas. The occipital foramen is large, and in some species is divided by a tentorial bridge. In most species, two divergent frontal sutures extend anteriorly toward the antennae, enclosing a large, triangular frons. On the ventral surface of the head, a gula may be present, or there may be only a median suture.

The prothorax is usually larger than the other two thoracic segments and forms a sheath for the posterior portion of the head. It is because of the size and shape of the prothorax that the name "round-headed borers" has been given to these insects. The dorsal surface may be variously marked, and is usually pubescent on the anterior and lateral areas. Normally, it is lightly sclerotized. The legs, if present, are never very conspicuous, and never more than four-segmented.

The first six or seven abdominal segments bear fleshy ambulatory ampullae on the dorsal, and sometimes on the ventral surfaces, which enable the larva to obtain a purchase on the walls of its gallery.The ninth tergum may be simple, or modified with sclerotized plates or immobile urogomphi. The anal segment is always trilobed.

Larval Key to the Described Species of Cerambycidae That May Occur in Fire-killed Pine in Ontario

Although the following key was designed for the identification of larval material collected during this study, it may have a wider application. All species reported to breed in pines, whether found during the present study or not, have been included to enhance the key's usefulness. Although no attempt has been made to place the species in phylogenetic order, the subfamilies occur in their accepted sequence. Most of the characters employed have been taken from Craighead's key (1923), the notable exceptions being those for *Acmaeops proteus* and *Acanthocinus pusillus*, which were not studied by him.

1. Legs usually present and well developed, but if absent or vestigial, then mandible with a gouge-like cutting edge. Head transverse to subquadrate, wider behind middle 2

Legs absent, mandibles with an oblique cutting edge. Head oblong, sides parallel or converging behind 14

2. Mandible with an oblique cutting edge, legs present 3
Mandible with a gouge-like cutting edge, legs present or wanting 11
3. Ambulatory ampullae never tuberculate, always micro-asperate; ninth tergum with a pair of short urogomphi 4
Ambulatory ampullae always tuberculate, and sometimes asperate; ninth tergum sometimes with a terminal spine, usually simple 5
4. Urogomphi fused, bifurcate at apex (Fig. 1) ..... *Tetropium cinnamopterum* Kirby
Urogomphi separated, acute-tipped (Fig. 2) ..... *Asemum atrum* Eschscholtz
5. Frons divided by a transverse suture (Fig. 3) 6
Frons not transversely divided 7
6. Ninth tergum bearing an acute, sclerotized spine, one pair of ocelli present ..... *Evodinus monticola* (Rand.)
Ninth tergum simple, five pairs of ocelli present (Fig. 3) ..... *Acmaeops proteus* Kirby
7. Head wider than prothorax, ampullae semi-tuberculate at the sides (Fig. 4) ..... *Rhagium inquisitor* (L.)
Head not wider than prothorax, ampullae distinctly tuberculate 8
8. Mesonotum tuberculate 9
Mesonotum not tuberculate 10
9. Three pairs of ocelli present ..... *Leptura subhamata* Rand.
One pair of ocelli present ..... *Anoplodera chrysocoma* (Kby.)
10. Metanotum bearing a central group of tubercles ..... *Typocerus velutinus* (Oliv.)
Metanotum pubescent, not tuberculate ..... *Anoplodera canadensis* (Oliv.)
11. Legs present 12
Legs absent 13
12. Gena shouldered, enclosing ocellus; ventral margin of the buccal fossa with a distinct tubercle behind the ventral mandibular articulation ..... *Callidium violaceum* (L.)
Gena not shouldered, no subfossal tubercle ..... *Neoclytus muricatulus* (Kby.)
13. Ocellus the size of the basal joint of the maxillary palpus ..... *Xylotrechus undulatus* (Say)
Ocellus smaller ..... *Xylotrechus sagittatus* (Germar.)
14. Ninth abdominal tergum with a sclerotized process or plate 15
Ninth abdominal tergum simple 16
15. Dorsal abdominal ampullae with a median furrow, wrinkled, but not tuberculate; ninth tergum with a large, longitudinally carinate plate ..... *Pogonocherus mixtus* Hald.
Ampullae more decidedly tuberculate, plate on the ninth tergum reduced to a mere point, or one or two carinae ..... *P. penicillatus* Lec.
16. Gula raised, dorsal abdominal ampullae with four rows of tubercles (Fig. 5) ..... *Monochamus* spp.
Gula not distinct 17
17. Dorsal abdominal ampullae irregularly tuberculate ..... *Astylopsis sexguttata* (Say)
Dorsal ampullae not tuberculate, velvety pubescent (Fig. 6) ..... *Acanthocinus pusillus* Kirby

Notes on the Insect Species Found

The following notes concern only those species found in the Mississagi fire area, either as larvae in the trees examined, or as adults encountered in the area during the progress of field studies. The species are placed in order of economic importance. Larvae of the species most common in the fire-killed pine are shown in Fig. 15.

***Monochamus notatus* (Drury), *M. scutellatus* (Say), and *M. mutator* Lec.**

It has not yet been possible to separate the larvae of these three species, either on the basis of the characters given by Craighead (1923) or otherwise and since they behave in much the same manner, they are considered together. The life histories and habits of *Monochamus* species have been well described by Craighead (1923, 1950), Simpson (1951), and Belyea (1952). The female chews a slit in the bark, inserts her ovipositor in the slit, and deposits one or more eggs in the inner bark. The larvae feed for three or four weeks on the inner bark and outer layer of sapwood, then enter the wood (Fig. 7). They commonly excavate a U-shaped tunnel that extends into the heartwood and turns back toward the surface, being enlarged at the end to form a pupal chamber (Fig. 8). The adult emerges by chewing a hole through the remaining wood and bark. Complete

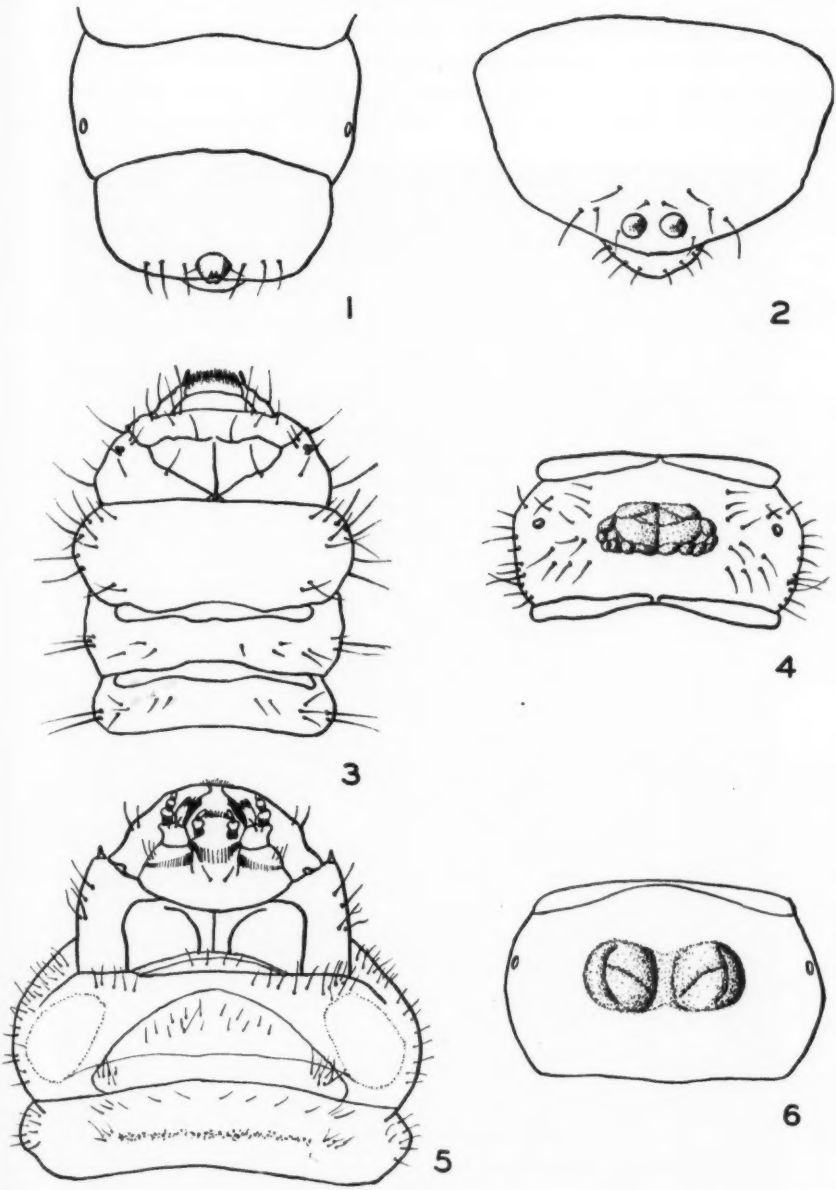

Fig. 1. Terminal segments of *Tetropium cinnamopterum* larva showing fused urogomphi.
Fig. 2. Terminal segment of *Asemum atrum* larva showing separate urogomphi.
Fig. 3. Head and thorax of *Acmaeops proteus* larva showing divided frons.
Fig. 4. Abdominal segment of *Rhagium inquisitor* larva showing dorsal ampulla.
Fig. 5. Ventral aspect of head of *Monochamus* larva showing prominent gula.
Fig. 6. Abdominal segment of *Acanthocinus pusillus* larva showing dorsal ampulla.

development usually requires two years, but in many cases adults emerged from fire-killed pine after the insects had been in the trees for only one year.

The adults were active in the fire area from mid June until early September, the peak of activity occurring in the last week of July. These species have been recorded as breeding in most of the eastern conifers, and were found or reared

Fig. 7. Surface mines of *Monochamus* larva under white pine bark. Note oval entrance hole in lower left side of photo.

Fig. 8. Typical U-shaped *Monochamus* gallery in white pine. Entrance hole on the right, pupal cell and exit hole on the left.

in the three species of pine during the present study. The first two showed a definite preference for white pine. *M. mutator* appeared to favour jack pine.

Asemum atrum Esch.

This insect is widely distributed in North America and breeds in Douglas fir, spruce, fir, and larch (Chamberlin, 1949). The female deposits her eggs under bark scales, and the young larvae, after a period of boring in the inner bark, mine extensively in the sapwood and outer heartwood, leaving galleries filled with a mixture of fibrous and pellet-like frass. From one to three years are required for complete development, the insects pupating in the sapwood or inner bark. When heavily infested wood was split open, it was impossible to trace individual galleries as in the case of many other cerambycids; it was simply honeycombed in apparently haphazard fashion. The adults are active throughout the summer months.

Xylotrechus sagittatus (Germ.) and *X. undulatus* (Say)

Since the habits of these two species are similar they are considered together. Oviposition occurs in the bark, the larvae feeding on the surface of the sapwood for a time before entering the wood (Fig. 9), in which they excavate extensive mines. The galleries are filled with a fine, floury frass. The mines in the wood are often restricted to a single annual ring. Pupation takes place in the wood, and the adults emerge by cutting an oval exit hole through the wood and bark. Craighead (1923) states that the same tree is usually attacked repeatedly from the time it dies until it is well decayed. Larvae were found in white spruce that had been dead at least two years, at which time the mines extended inwards to a depth of three or four inches. These insects were also found or reared in all three species of pine, and have been recorded as breeding in the spruces, fir, and hemlock (Craighead, 1923).

Tetropium cinnamopterum Kby.

This insect has been reported from larch, pines, fir, and spruce (Craighead, 1923). In the Mississagi area, it was found breeding freely in all three pines. The eggs are deposited beneath bark scales, and the larvae bore into the inner bark, where they feed for a season before constructing a shallow pupal cell in the sapwood (Fig. 10). Hopkins (1899) reported having found larvae mining in the bark of living trees. In the Mississagi area, although it was common to find adults under the bark scales of healthy red pine trees, no oviposition was evident. Larvae were found, however, in fire-damaged trees that were in the early stages of dying, the cambial region still being fresh. Development in fire-killed pine was completed in one year.

Acmaeops proteus Kby.

The most numerous of all species of cerambycids found in the fire-killed trees, this species has been reported breeding in pine, spruce, and balsam fir (Morley, 1939). Large numbers were found in all three pines that had been killed by the fire. The life history is not well known, the manner of oviposition and pupation being obscure. The larvae feed gregariously in the phloem, converting it to a mass of coarse frass (Fig. 11). The total time required for development is not known, but larvae were found under the bark of trees that had been dead for two years. No pupae were found under bark, so pupation is believed to take place in the soil. Larvae were also found in dead branches on living trees. A description of the mature larva of this species has been published (Gardiner, 1954).

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***Acanthocinus pusillus* Kby.**

This species occurred in all three species of pine in the fire area, although white pine appeared to be preferred. They do not enter the wood, but feed under the bark, where they were often found in large numbers. The eggs are laid in slits chewed in the bark by the female, or in bark beetle holes. Development normally takes one year. Pupation occurs in the bark, and in the present study, adults emerged from caged material by chewing an oval hole.

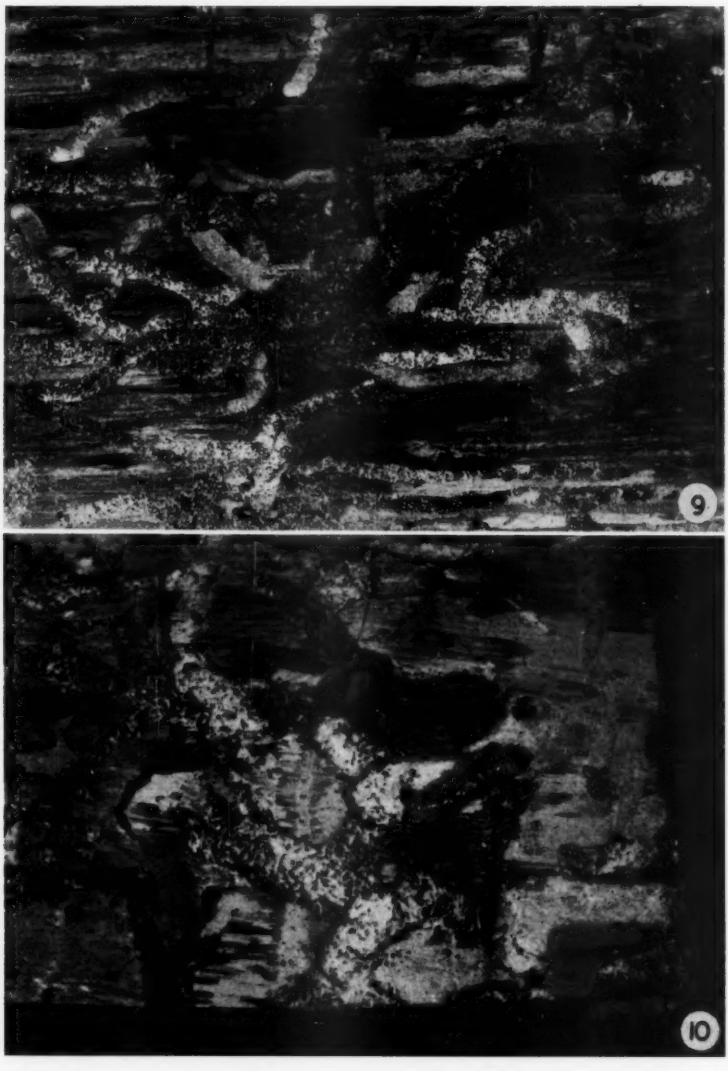

Fig. 9. Mines of *Xylotrechus undulatus* larvae under white pine bark. Note powdery frass.
Fig. 10. Work of *Tetropium cinnamopterum*, with beginning of pupal cell above the larva's head.

These insects can attack trees that have been dead only a very short time. In the Mississagi area newly hatched larvae were found, usually with *Tetropium* larvae, in the "fresh" phloem of trees that were just on the verge of death. A description of the mature larva has recently appeared (Gardiner, 1955).

***Rhagium inquisitor* (L.)**

This species is widely distributed throughout Canada, the United States, and Mexico wherever pine is found (Hess, 1920). The eggs are laid early in the spring in the bark crevices of pines and many other conifers, and the flat, broad-headed larvae feed extensively beneath the bark. In the autumn, the insect constructs an oval pupal cell of frass and chips between the bark and wood, and passes the winter either as an adult or a pupa (Fig. 12). Craighead (1923) states that they prefer trees that have been recently killed, and adults were observed on the bases of trees that had been damaged by fire but were still alive. No evidence of oviposition or successful attack in these trees was obtained, however. A good account of the biology of this species has been given by Hess (1920).

***Arhopalus agrestis* (Kby.)**

This insect was found only as adults in the fire area, and not in large numbers. Chagnon (1938) reports it as breeding in dead pine in Quebec, and Knull (1946) records that it works in the base of dead pine and spruce trees. There seems to be very little known of its habits and life history.

***Anoplodera chrysocoma* (Kby.)**

The adults of this species were found in considerable numbers in the fire area on flowers, especially the common daisy, but no larvae were among those collected from sample blocks. Adults have been reared from *Pinus flexilis* James and *P. ponderosa* Laws. in the West (Craighead, 1923), and Knull (1946) states that it is recorded as breeding in dead pine. Little is known of its habits.

***Anoplodera canadensis* (Oliv.)**

Adults of this species were collected from the trunks of dead and dying pines, but the larvae were not identified in sample blocks. Knull (1946) reports that it has been recorded as breeding in dead pine, spruce, and hemlock. According to Craighead (1923), it commonly attacks the heartwood of living trees by gaining entrance through a wound. Its distribution is widespread throughout the range of its host tree species.

***Callidium violacem* (L.)**

Adults were found in small numbers, but no larvae were obtained from the sample blocks. Chagnon (1938) records that the larvae live in conifers. Little appears to be known of its habits.

***Neoclytus muricatulus* (Kby.)**

A few adults of this species were collected, but no larvae. Craighead (1923) states that it occurs throughout the range of the spruces, and that it completely riddles the small branches of spruce, larch, Douglas-fir, and pines. He also states that it is found in living conifers. Very little is known of its life history.

***Astylopsis sexguttata* (Say)**

A small number of adults were found in the study area, but no larvae were present in sample blocks. Very little is known of this insect. Craighead (1923) records it as feeding between the bark and wood in pine and spruce, pupating in the outer layer of sapwood. The adults are probably active throughout most of

the summer; Craighead states that they fly during April and May in the eastern United States, and they were collected in the Mississagi area during August.

***Pogonocherus mixtus* Hald.**

Adults of this species were found on the bark of fire-damaged pine, but no larvae were collected in sample blocks. They have been reported breeding in the branches of pine and spruce (Craighead, 1923), but, other than this report there appears to be very little known about this species.

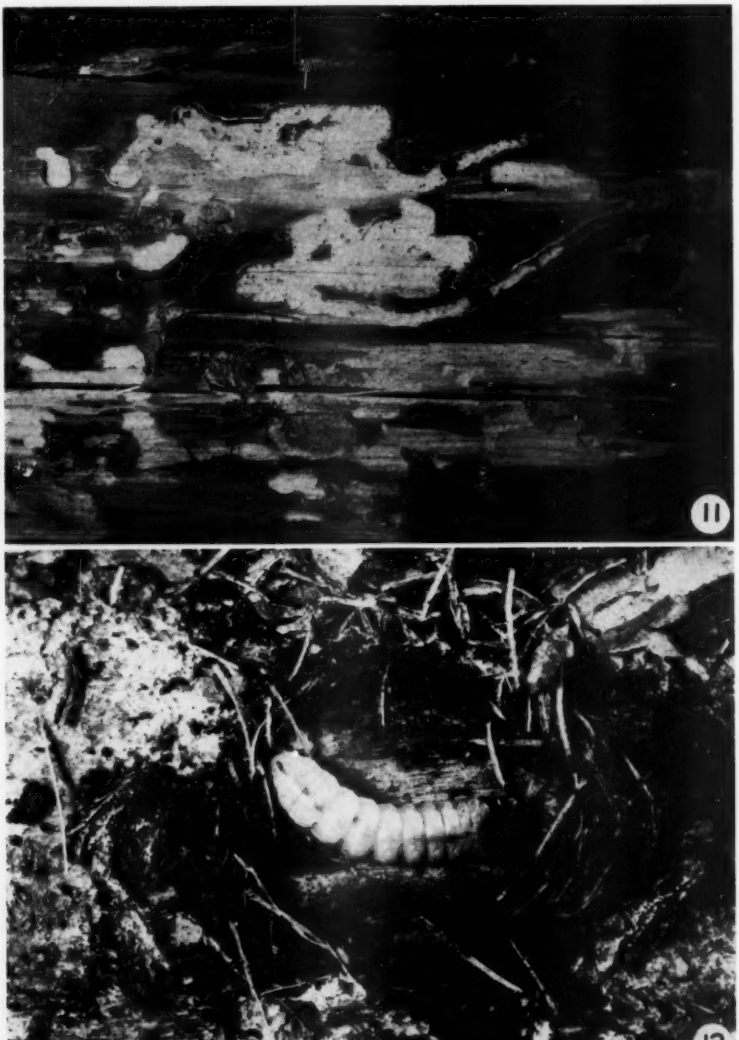

Fig. 11. Mines of *Acmaeops proteus* under white pine bark.
Fig. 12. *Rhagium inquisitor* larva constructing pupal cell under red pine bark.

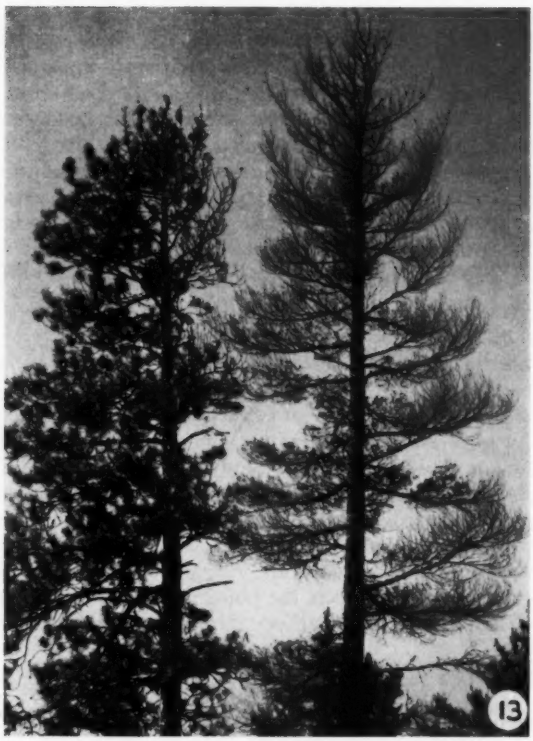

Fig. 13. Difference in effect of fire on red pine (left) and white pine (right). Trees were six feet apart and had been exposed to the same ground fire. Cambium of white pine was killed.

Effects of Fire on Pine Trees

Susceptibility of Different Pines to Damage by Fire

It was apparent, even from early general observations in the fire area, that the three species of pine were affected by fire to different degrees. In almost all jack pine stands, all trees were severely burned and killed outright, and even in the more open stands, where burning was less severe, most of the trees eventually died. White pine stands also showed heavy damage but to a lesser extent, there being a greater variety in burn severity in white pine. The situation in red pine stands was notably different, however. Here, in spite of evidence of very heavy ground fire (shrubs and debris consumed, and fallen trees heavily charred), frequently a large percentage of the trees remained virtually unaffected by the heat. Where the three species occurred together, it was usual to find that the jack pine had been killed outright by the fire, much of the white pine had been killed or was dying, but the bulk of the red pine was still alive, forming islands of living trees surrounded by dead forest. Many examples were noted where white and red pine trees only a few feet apart showed marked difference in vulnerability. Fig. 13 shows one such case in which the white pine was heavily charred throughout its entire length and killed outright, while the red pine, some 6 feet away, was only lightly charred on the basal 20 feet of the bole and was in good health a year after the fire.

It is probable that this variation in susceptibility to fire damage is the result of physical differences in the three species. Of the three, mature jack pine has the thinnest bark. The bark on the other two species is roughly equal in thickness, but the structure and colour are markedly different. The bark of white pine is solid, except for deep fissures that extend inwards almost to the phloem, while that of red pine is scaly in the outer portion and not so deeply fissured. The bark of white pine is a very dark grey, and that of red pine a light reddish-brown. It is probable that the solid bark of white pine provides better heat transfer than the scaly bark of red pine, and that the deep fissures in the former allow the heat to penetrate quickly to the vulnerable cambial region. It also seems reasonable that the darker bark of white pine would absorb more heat in a given length of time.

Relationship of Fire Injury to Insect Attack

As previously mentioned, Richmond and Lejeune (1945) were able to relate borer attack to severity of burn in fire-killed spruce in northern Saskatchewan. They recognized five types of burn of different severity, based on the extent of char on logs, the most severe of which was permanently immune to attack by borers because the bark was burned thin and the cambium cooked. Moderately charred logs were attacked earliest and principally by deep-boring species, whereas shallow-boring species predominated in the lightly charred logs. During the course of the present study it soon became clear that there was not the same relationship between severity of bark charring and insect attack in burned pine. The thicker bark effectively protects the phloem and cambium so that, regardless of severity of charring, no burn type occurs in which the wood is permanently unattractive.

In view of the fact that other authors have been able to relate borer attack to charring, the extent of bark charring on the trees and blocks examined during the present study was recorded as light, moderate, or heavy. Superficial charring of the bark was recorded as light. This char could easily be scraped away and was, in fact, eventually removed by the weather to great extent on the standing trees. Charring that penetrated beyond the outer scales but that did not go deeply into the bark fissures was designated as moderate. Charring was recorded as heavy when it extended deeply into the bark and no uncharred bark could be seen on the surface or in the fissures. Damage to the crown was also recorded.

The data obtained did not lend themselves to statistical analysis; however, careful inspection failed to reveal any relationship between insect attack and either extent of bark charring or height in tree.

Because of this, interest became centred around the standing, burned tree

TABLE II

Relationship between burn severity and time of death of white, red, and jack pine trees

Fire Injury Class	No. of Trees described	Percentage of trees that died at various times					Total mortality (%)
		Summer 1948	Winter 1948–49	Summer 1949	Winter 1949–50	Summer 1950	
1	160	61.0	29.0	6.0	4.0		100.0
2	45	4.5	29.0	20.0	9.0	13.0	75.5
3	27			22.0	26.0	11.0	59.0

as the principal unit of investigation. Study of the burn descriptions showed that the sample trees distributed themselves in 3 *fire injury classes* based on time of tree death. Table II gives the percentage of all trees examined, in each class, that died at various times after the fire. The tree species have been grouped, since the picture was the same in regard to all three. All of the Class 1 trees died, 90 per cent of them during the six-month period following the fire. Serious mortality in the Class 2 trees did not begin until six months after the fire and about 25 per cent survived for at least two years. In the Class 3 trees, no mortality occurred during the first year and at the end of two years only 59 per cent had died.

General descriptions of the three classes are as follows:

Class 1. *Severe injury* —trunks charred throughout entire length, with heavy charring on at least the lower 20 to 35 feet, char extending deep into bark and fissures, bark scales burned off in red pine, foliage almost entirely killed or consumed;

Class 2. *Moderate injury*—trunks heavily charred at base and lightly at 20 feet or higher, or lightly charred over entire length, killing of foliage variable but rarely any consumed;

Class 3. *Light injury* —trunks lightly charred on the lower 20 to 35 feet at most, partial killing of foliage in some cases, but crown usually intact and green.

While no consistent relationship between extent of charring and borer attack in trees that died at the same time was indicated by the data available, it was found that the time of tree death, which is influenced by the severity of fire injury sustained, directly affected the time and nature of insect infestation.

All of the wood-boring beetles found in the Mississagi fire-killed pine are commonly referred to as "secondary forms"; i.e., they are incapable of causing the death of the host, and only occur in trees that are dead or dying from some other cause. Thus, trees were only found to be infested when they were either dead or dying. Those that suffered severe fire injury died and became infested shortly after the occurrence of the fire. Moderately injured trees died, for the most part, during the first winter and became infested the following spring; whereas lightly injured trees usually escaped infestation for at least a year after the fire.

The severity of fire injury, by influencing the time of tree death, was also found to affect, indirectly, the complex of borers subsequently infesting the tree. This phenomenon, also noted in fire-killed spruce by Richmond and Lejeune (1945), is of great importance in the salvage of fire-killed timber. Table III gives the number of entrance holes of all borer species per square foot of wood surface, and the percentage of them made by *Monochamus*, in trees that were killed outright and in others that died during the winters of 1949-50 and 1950-51. In white and red pine, the proportion of holes made by *Monochamus* species was greater in trees that were killed outright than in those that died later. In the latter, the shallow-boring species predominated. Those trees that died during one of the winters following the fire, when there were no adults abroad in the field, remained uninfested until the following spring. The bark beetle *Ips pini* becomes active earlier than *Monochamus* species and thus had the first opportunity to attack these trees. Such cerambycids as *T. cinnamopterum*, *A. proteus*, and *A. pusillus* also possess the same advantage over *Monochamus*. These insects, and the bark beetles, were able to pre-empt most of the bark area susceptible to

TABLE III

Number of entrance holes of all borer species per square foot of wood surface and percentage made by *Monochamus* spp.

Tree Species	Time of tree death					
	Summer 1948*		Winter 1949–50*		Winter 1950–51†	
	Sq. ft. examined	Holes	Sq. ft. examined	Holes	Sq. ft. examined	Holes
white pine	142.9	1.92 65%	173.6	1.30 31.4%	48.33	5.42 31.7%
red pine	187.2	2.40 26%	78.9	5.38 0.7%	47.9	8.55 3.0%
jack pine	81.9	1.96 68%	–	–	–	–

*Examined during summer of 1950.
†Examined during summer of 1951.

attack. Thus, the proportion of *Monochamus* larvae found in these trees was lower than in trees killed at a time when *Monochamus* adults were active.

The predominance of shallow-boring species was not restricted to trees that died during the winter, however; trees that died slowly during the summer months were also less heavily attacked by *Monochamus* than were trees that were killed quickly. Again, this appeared to be the result of pre-emption of food and space by other species. Howden and Vogt (1951) found that bark beetles entered dying Virginia pine before cerambycids and the same sequence was observed in slowly dying pine injured in the Mississagi fire. Trees were infested by *Ips*, often in company with *Acmaeops* and *Tetropium*, when the phloem was still in the "fresh" condition and before any *Monochamus* eggs had been laid. That the absence of *Monochamus* larvae in these trees was not due to an absence of adults in the area was shown by slowly dying jack pine trees examined during the summer of 1949. Some of these had already been heavily infested by *Ips* and *Acmaeops* bore as many as 33 *Monochamus* egg slits per square foot of bark surface; yet none of these had been used for oviposition. Apparently, *Monochamus* females were reluctant to lay eggs in trees that had not reached a certain point in drying or that already harboured other insects in abundance.

In support of this explanation, the following observations may be cited. In early July, 1949, the writer observed the activities of a female *M. scutellatus* on a red pine log that had been cut during the previous winter. The insect made her way slowly over the log with her antennae continuously brushing the bark surface, her head moving from side to side. At frequent intervals, she cut an egg slit and inserted her mandibles deeply into the bark, remaining motionless, with her body and antennae pressed close to the bark, for a considerable length of time. She would then rise, pass on to another spot, and repeat the process. In this way, over twenty egg slits were chewed, with none being used for oviposition, and eventually the insect flew away. Subsequent examination of the log showed that the entire phloem region harboured an extremely heavy infestation of bark beetles.

It seems possible that a difference in borer species complex in trees dying at different times may only occur in the case of late spring or summer fires, since

TABLE IV
Average number of larvae per square foot of wood surface in blocks for which complete population records were obtained

	Tree Species	Insect Species Present				
		Monochamus spp.	*Acmaeops proteus*	*Tetropium cinnamopterum**	*Acanthocinus pusillus*	*Xylotrechus* spp.
Died during Winter 1948–49 Examined during Summer 1949	White pine 21 blocks	0.31	1.91	–	2.14	0.20
	Red pine 29 blocks	0.09	3.05	–	0.27	0.00
Died during Winter 1949–50 Examined during Summer 1950	White pine 35 blocks	0.62	1.26	0.46	4.48	0.01
	Red pine 32 blocks	0.03	0.31	6.02	0.20	0.00

*Precise data on this species not obtained in 1949.

the intensity of *Monochamus* attack appears to depend on the time and nature of tree death. Trees that were killed outright in the Mississagi fire died quickly during the month of June when *Monochamus* adults were just becoming active in the field. Large numbers of adults apparently entered the area, attracted by the smoke or volatile substances in it, and laid eggs in most of the killed trees regardless of tree species. Although no data are available for comparison, it seems probable that in the case of an autumn fire trees would not be damaged by *Monochamus* to the same extent, but would likely remain uninfested throughout the winter; then be attacked in the spring first by bark beetles and shallow-boring cerambycids. These insects might utilize so much of the inner bark that there would be little or none available for the later-emerging *Monochamus*.

It may be concluded from the results of this study that insect infestation in fire-damaged pine is primarily affected by the time and nature of tree death, which influence both the time of insect attack and the complex of species comprising the infestation. The time and nature of tree death are, in turn, governed by the degree of fire injury; and may, in general, be predicted for any burned pine tree by ascertaining, through examination of the trunk and crown, the *fire injury class* in which it falls.

Borer Population Differences in White and Red Pine

It became evident during the study that there was a difference in insect population in these two species of pine. Table IV gives the average numbers of larvae of different species per square foot of wood surface found in sample blocks from trees that died during the winters of 1948-49 and 1949-50. In compiling these data, only those blocks for which complete population records were obtained were used. The white pine blocks of both groups bore larger numbers of *Monochamus* spp., *A. pusillus*, and *Xylotrechus* spp., while larger populations of *T. cinnamopterum* were borne by the red pine blocks. No clear population differences in *A. proteus* occurred in blocks of the two tree species.

TABLE V

Percentage of trees and blocks infested by *Monochamus* spp. and *Tetropium cinnamopterum*

	Tree Species	Percentage infestation			
		Monochamus species		*Tetropium cinnamopterum**	
		Trees	Blocks	Trees	Blocks
Died during Winter 1948–49, Examined during Summer 1949	White pine 9 trees, 21 blocks	100.0	62.0	–	–
	Red pine 10 trees, 29 blocks	60.0	24.1	–	–
Died during Winter 1949–50, Examined during Summer 1950	White pine 8 trees, 35 blocks	100.0	60.0	87.6	71.4
	Red pine 8 trees, 32 blocks	25.0	6.3	100.0	100.0

*Precise data on this species not obtained in 1949.

Further evidence suggested that these population differences arose probably through host preferences, at least in respect to *Monochamus* and *Tetropium*. Table V, which gives the percentage of trees and blocks infested by *Monochamus* and *Tetropium* larvae, shows that the percentage of both trees and blocks attacked by *Monochamus* was higher in white pine than in red, in both groups of trees that died at different times. Populations of *Tetropium* larvae in trees that died during the winter of 1948-49 were not analysed since the true number was obscured by the fact that a number of larvae had entered the wood by the time of examination and because no distinction was made between the types of entrance holes on the wood surface during the 1949 field season. However, average densities of larvae in blocks from trees that died during the following winter, and the percentage of trees and blocks infested (Tables IV and V), show that fewer white pine blocks were attacked by this species, and, in those that were, infestation was lighter than in infested red pine blocks. It is interesting to recall that this insect lays its eggs under bark scales, a habit to which the bark of red pine is much better suited than is that of white pine.

Another indication that *Monochamus* species prefer white pine to red was shown by daily counts of adults on 12 "trap trees" of each species made during the summer of 1951. Table VI gives the average numbers of adults counted per tree during the period when they were most active. The number counted on white pine was approximately twice that on red pine trees. These trees were all approximately the same size, and were located in the same area.

Depth of *Monochamus* Penetration

Table VII gives the mean, average maximum, and maximum depth of borer galleries appearing on radial faces in all three species of pine examined at different times after tree death. The data are segregated by block diameters, and, in compiling them, only galleries at a depth of one and a half inches or deeper were counted, so as to exclude *Tetropium* pupal cells in the sapwood. It is emphasized

TABLE VI

Average number per tree of *Monochamus* adults counted on 12 white pine and 12 red pine "trap" trees between July 13 and August 1, 1951

Tree Species	Insect species	
	M. notatus	*M. scutellatus*
White pine	92.0	14.8
Red pine	44.5	8.3

that these data do not represent measurements made on individual *Monochamus* tunnels, but are calculated from the measured depths of galleries appearing as holes in the radial faces exposed by splitting the sample blocks.

Penetration by *Monochamus* larvae was deepest in white pine and shallowest in red pine, that in jack pine being intermediate. The mean depth of galleries in white pine ranged from 3.4 to 4.2 inches and from 1.8 to 3.5 inches in red pine, in blocks that had undergone a well developed or complete attack at the time of examination. The mean gallery depth in jack pine ranged from 2.5 to 3.6 inches.

In white pine, the maximum depth of individual galleries approximated half the block diameter in blocks up to about 18 inches in diameter, the greatest depth of penetration recorded during the present study being 9.5 inches. Table VII shows, however, that this only holds for isolated galleries, there being no consistent increase in the *average maximum depth* of galleries in blocks of increasing diameter. This suggests that *Monochamus larvae* are generally restricted in the

TABLE VII

Mean, average maximum, and maximum depth in inches of borer galleries in white, red, and jack pines at different times after death of the trees and in blocks of different diameters. Galleries appearing on split radial faces

Diameter of Block in Inches	Time elapsed after death of tree											
	3 months*			12 to 13 months			14 to 15 months			24 months		
	Mean	Ave. Max.	Max.	Mean	Ave. Max.	Max.	Mean	Ave. Max.	Max.	Mean	Ave. Max.	Max.
WHITE PINE												
10–14	2.9	4.4	5.5	3.8	5.2	6.0	4.2	6.1	7.0	3.4	4.6	6.5
14–18	2.8	5.1	9.0	3.9	5.3	8.0	3.7	5.8	7.0	4.2	6.1	6.0
18–	–	–	–	3.9	5.0	8.0	3.4	5.3	7.0	3.8	4.1	9.5
RED PINE												
–10	–	–	–	–	–	–	–	–	–	3.1	4.3	6.0
10–14	–	–	–	2.5	2.7	4.0	2.8	3.6	5.0	3.3	3.7	5.0
14–18	–	–	–	2.1	2.3	4.0	1.8	2.0	2.5	3.5	3.6	6.0
JACK PINE												
–14	–	–	–	2.6	4.0	6.5	2.9	5.3	6.0	–	–	–
14–	–	–	–	2.5	3.2	5.5	3.6	4.3	5.0	–	–	–

*trees attacked early in the summer of 1949 and examined in the autumn.

Fig. 14. *Monochamus* tunnel in white pine; a departure from the usual shape.

depth to which they tunnel in all three species of pine studied. This tends to support a theory proposed by Trägårdh (1930) in respect to tunnelling by the European species *M. sutor* (L.). He observed that the larvae bored inward to a depth of about 7 cm. during the first season. If the diameter of the trunk were not much greater than twice this distance, the larva spent the winter at the centre of the tree, and its burrow the following year might take any direction. If the diameter of the trunk were much greater than 14 cm., the larva spent the winter closer to one side of the tree (the entrance side), and doubled back the following year to form a U-shaped tunnel. Trägårdh stated that it was obvious that the insect could tell the shortest distance to the outside of the tree, and suggested that temperature played an important part in this perception. In the present study, at least one case was noted in which a larva tunnelled through a tree and emerged from the other side (Fig. 14), the tree being approximately 11 inches in diameter at this point.

The average maximum depth of galleries in white pine appears to have been between 5 and 6 inches (Table VII), which closely agrees with the radius of the tree mentioned above. This suggests that the outer six inches of any white pine log, regardless of its size, is susceptible to damage by these insects. In jack pine, the average maximum depth of galleries was between 3 and 5 inches, and in red pine between 2 and 4 inches. The wide range in each case may be due to there being more than one species of *Monochamus* in the fire-killed timber. *M. notatus*, being larger than either of the other two species, may penetrate more deeply into the wood.

Duration of Insect Damage

The duration of damage by a wood-boring beetle depends, of course, on the length of its developmental period. Most of the shallow-boring species complete development in one year, and in trees infested with these alone, damage was completed rapidly and was of little consequence. In trees infested by deep-

TABLE VIII

Number of galleries appearing at 2 inches or deeper per 12 lineal feet of radial face—White pine—Killed summer of 1948

Diameter class of block, inches	Time of Examination	
	June, 1949	Aug. to Sept., 1949
11–13	8.0	14.7
	(4)*	(16)
14–16	5.7	10.7
	(18)	(13)
17–19	4.0	7.6
	(16)	(5)
20–22	1.0	3.2
	(6)	(4)

*Number of blocks examined.

boring species, which normally take two years to complete development, damage extended over a longer period and was consequently much heavier.

By the end of a season of *Monochamus* infestation, most larvae had penetrated to their maximum depth. As shown in Table VII, the average maximum depth at this time was little less than that in trees examined two years after attack. In trees killed outright in the summer of 1948, therefore, the depth of *Monochamus* penetration was probably much the same as in the following June when the first trees were examined. Maximum damage had not been done to the wood, however, because the larvae extended their galleries back toward the log surface during the second season, thereby increasing the amount of tunnelling in the wood. Table VIII gives the number of *Monochamus* galleries appearing on 12 lineal feet of radial face in blocks of different diameters from trees that died during the summer of 1948. Holes at depths of less than one and a half inches have been ignored in order to exclude *Tetropium* pupal cells. The frequency of borer holes on radial faces in the late summer of 1949 was, for each diameter class, approximately twice as great as in the spring. Material examined in 1950 showed no further increase in frequency of holes. Direct damage by deep-boring *Monochamus* larvae had therefore attained its maximum about 15 months after initial attack in fire-killed trees. Such rapid deterioration of the valuable outer portion of the tree severely restricts salvage success in an extensive burn and makes speed essential.

Summary and Conclusions

Seventeen species of cerambycids known to attack conifers were found active in the Mississagi area during the three-year period after the fire of 1948. Notes on the habits of these species and a key for the identification of their larval forms have been given. By far the greatest damage done to the fire-killed pine was caused by the larvae of *Monochamus* species, which bore deeply into the wood. The outer six inches of any white pine log was found to be susceptible to damage by these insects, with occasional larvae tunnelling as deep as 9.5 inches from the wood surface. Penetration was less deep in jack and red pines.

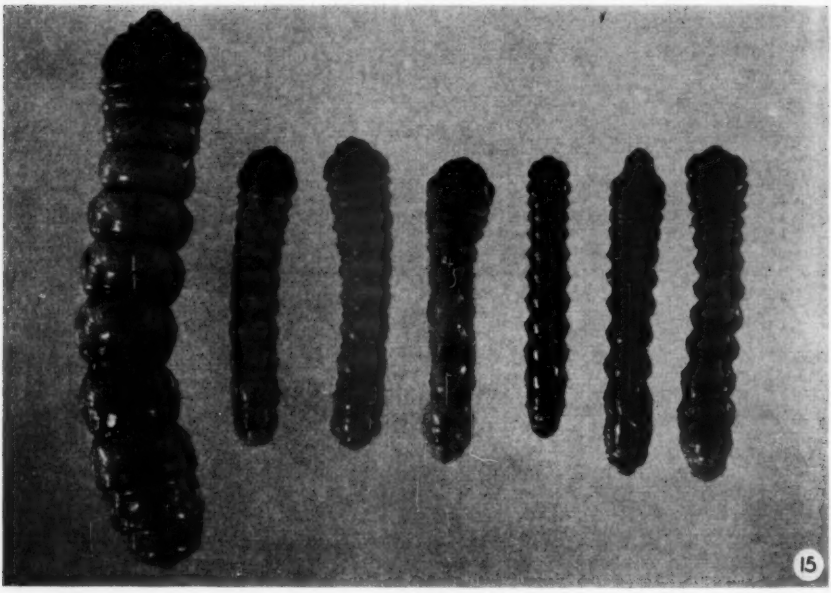

Fig. 15. Mature cerambycid larvae found infesting fire-killed pine. Left to right: *Monochamus* sp., *Asemum atrum*, *Xylotrechus* sp., *Tetropium cinnamopterum*, *Acmaeops proteus*, *Acanthocinus pusillus*, *Rhagium inquisitor*.

Certain of the results of this study appear to be of value in the planning of salvage operations in eastern Canadian pine stands devastated by summer fires:

First, it was found that the effects, both direct and indirect, of fire on pine vary greatly with species. Initially, there appears to be a basic difference in susceptibility to fire injury; jack pine succumbs very readily, followed by white and then red pine. This is important in view of the observation that severity of burn injury governs the speed and nature of insect attack. In addition, it has been found that, other things being equal, infestation by harmful, deep-boring species is considerably heavier in white pine than in red, and penetration of the larvae into the wood is deeper. Thus, it is obvious that after fires involving white and red pine the more valuable white pine should, if possible, be salvaged first. There is a corollary of this, of course; dead red pine would probably be more valuable than dead white pine one or two years after a fire.

Secondly, it has been shown that the severity of burn injury suffered by a tree, by influencing the time at which the tree dies, governs the insect damage it will sustain. Thus, severity of fire injury indicates the time to salvage in order to minimize losses after summer fires. Trees suffering severe fire injury will receive the earliest attack and the heaviest damage from deep-boring insects, and should be salvaged as soon as possible. It may be uneconomic to attempt salvage of any but the larger trees of this class on a large burn. Moderately injured trees may be left until the following summer, but it would be more desirable to cut them during the winter following the fire when they are still in good condition. Trees suffering only light injury will, in general, be free from serious damage for at least a year, and need not be cut until then. Since many of these trees will survive, it is possible that they would be of greater value

if left for the purpose of providing seed for the regeneration of desirable tree species on the burn. This was done in some stands in the Mississagi area, and an examination six years after the fire showed that most of the trees were still alive, with reproduction of white and red pine being best where this practice had been carried out.

Acknowledgments

Grateful acknowledgment is made of the interest and help of Prof. E. M. DuPorte and others of the Entomology Department, Macdonald College, Quebec.

Special thanks are given to Dr. M. L. Prebble, Chief, Division of Forest Biology, and members of the staff of the Forest Insect Laboratory, Sault Ste. Marie, especially the Officer-in-Charge, Dr. R. M. Belyea, for guidance and criticism. Adult insects were identified by personnel of the Systematic Unit, Division of Entomology, Ottawa. Photography was carried out by D. C. Anderson and C. S. Holling.

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(Received January 23, 1957)

Insects Affecting Seed Production in Red Pine
IV. Recognition and Extent of Damage to Cones[1]

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Introduction

The broad study of factors responsible for poor seed production by red pines (*Pinus resinosae* Ait.) in central and southern Ontario has been concerned with the seed production capacity and efficiency of sound cones (1) and the description, life history, behaviour, and natural control of cone-inhabiting insects (2, 3, 4). The present contribution, which concludes the four-part series on red pine cone insects, deals with the time and duration of cone attack by the various insect species and the variability in the intensity of cone damage from year to year and from one locality to another. As an aid to the field diagnosis of the cause of cone damage, keys based on the appearance of mature larvae and injured cones are included.

Identification of Insect Damage and Immature Cone Insects

Each species of red pine cone insect damages cones in a recognizably different manner. The following key to damage is especially applicable after damage is complete and the insects have left the cone. It may also be used while the insects are still active in the cone as long as it is remembered that withering and distortion of the cone may not yet have begun. Cones infested by more than one species are sometimes very difficult to diagnose, owing to obliteration of the typical characteristics, but such cones are relatively rare.

Key to Insects Infesting Red Pine Cones Based on Damage to Cone

1a Cone shrivelled, no seed release 2
1b Cone with scales affected only on one side, or normal with only seeds destroyed 6
2a Cone easily detached from branch, leaving a transversely grooved stub, most often dry and hard, with a waxy accumulation of resin covering scales at one side near base; with small circular holes mostly at stem end but sometimes in sides and top; containing dry, brown powder. Cone infested by *Conophthorus resinosae* Hopk.
2b Cone not as above; not usually as easily removed from branch, and when removed is devoid of a grooved stub 3
3a Cone with a conspicuous hole near but not adjacent to the petiole; when removed from branch leaves a jaggedly broken stub; containing frass pellets, spun silk, and crystallized resin; sometimes with frass and webbing on outside near base. Cone infested by *Dioryctria disclusa* Hein.
3b Cone lacking a conspicuous hole near base; sometimes with round or oblong holes near top 4
4a Cone containing crystallized resin between scales and around seeds; no webbing, frass pellets, or holes; scales sometimes sprung at outer ends. Cone infested by *Rubsaamenia* sp.
4b Cone containing frass pellets 5
5a Cone packed with a mixture of frass and resin when heavily infested; many inconspicuous round holes or a few conspicuous oblong holes in upper half; little or no frass ejected from cone; no webbing inside; sometimes easily removed from branch, but if so, leaves no transversely grooved stub. Cone infested by *Eucosma monitorana* Hein.
5b Cone with upper scales hollowed out; tunnels often empty, never containing tightly packed debris; quantities of frass sometimes clinging to outside of cone and held in place by webbing. Cone infested by *Dioryctria abietella* (D. and S.)
6a Cone appears normal but seeds inside destroyed, filled with debris, and held securely in place; mature and expanded cones sometimes with empty pupal cases protruding from seeds or scales. Cone infested by *Laspeyresia toreuta* Grt.
6b Cone not as above; obviously injured 7
7a Cone nearly full grown; scales on one side small and shrunken, with a conspicuous

[1]Contribution No. 348, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada.

hole near base on that side; containing frass pellets; some seeds perhaps released from uninjured region. Cone infested by *Dioryctria disclusa* Hein.

7b Cone with a few scales at sides or top distorted; no frass pellets; flakes of crystallized resin on inner surface of scales; some seeds perhaps released from uninjured region. Cone infested by *Rubsaamenia* sp.

The following key to mature larvae is offered as a supplementary aid to the diagnosis of damage. It includes secondary insects that may be found in damaged cones, as well as those responsible for damage.

Key to Mature Larvae of Insects Commonly Inhabiting Red Pine Cones

1a Larva with legs on thoracic and abdominal segments; typical caterpillar 2

1b Larva legless 9

2a Longest seta of second thoracic segment inserted in a sclerotized ring rather than in a solid sclerite 3

2b No such ringed seta 5

3a Dorso-lateral seta of eighth abdominal segment much longer than others, inserted in a sclerotized ring 4

3b Dorso-lateral seta of eighth abdominal segment of ordinary length, inserted in a solid sclerite. Larva 15-16 mm. long; colour grey to brown or green, unmarked; head, pronotum, epiproct, and legs dark orange-brown; setal sclerites dark brown and prominent. In a cavity inside cone or shoot ..... *Dioryctria cambiicola* (Dyar)

4a Epiproct entirely light brown or yellow, not darkening laterally; setal sclerites whitish, inconspicuous; background colour of body olive-green to purple-brown, with pale brown dorsal and lateral patches on each segment; length 13-18 mm. Larva tunnelling deeply inside cone ..... *Dioryctria disclusa* Hein.

4b Epiproct light brown or orange medially, darker brown laterally; setal sclerites dark but not conspicuous; body pale reddish-purple to maroon, sometimes with faint dorsal and subdorsal lines; length 15-25 mm. Larva tunnelling shallowly in cone ..... *Dioryctria abietella* (D. and S.)

5a Seta above spiracle on first seven abdominal segments surrounded by a crescentic sclerite opening dorsally; body dark brown with broken grey longitudinal lines; length 10-12 mm. Larva between scales of withered cones previously damaged by other insects ..... *Holcocera immaculella* McD.

5b No crescentic sclerites around spiracular setae 6

6a Larva white, patterned with red, 6-8 mm. long ..... *Recurvaria* spp.

6b Larva grey to yellow-white, not patterned with red 7

7a Head brown, with a black or dark brown spot on edge posterior to ocelli; about 12 mm. long. Tunnelling in green cones during July ..... *Eucosma monitorana* Hein.

7b Not as above 8

8a Body firm, white, opaque; thoracic segments distended, obviously wider than head; length 7-10 mm. Tunnelling in seeds or axis of apparently undamaged mature cone ..... *Laspeyresia toreuta* Grt.

8b Body soft, grey to white, translucent; thoracic segments not conspicuously wider than head; length 4-6 mm. Feeding in cavities of sound cones killed during the previous summer ..... *Duvita vittella* Bsk.

9a Larva with distinct head capsule 10

9b Larva with head reduced 11

10a Head small, black; body white, slender, cylindrical; 4-6 mm. long. Feeding in wet, rotting cones ..... *Lycoria pauciseta* (Felt)

10b Head pale brown and well developed; body white, stout, curved; about 4 mm. long. Feeding in recently killed cones ..... *Conophthorus resinosae* Hopk.

11a About 2 mm. long; slightly flattened; orange-pink to bright red-orange. In clusters between the scales of maturing cones, or in cones damaged by other insects *Rubsaamenia* sp.

11b Not as above; cylindrical 12

12a White, translucent, slender, elongate, pointed anteriorly and rounded posteriorly; 2-3 mm. long. Feeding on frass in cones killed by other insects ..... *Oscinella* sp.

12b Pink to orange; 2-3 mm. long. Predacious ..... *Lestodiplosis* sp.

Time and Duration of Insect Attack in Cones

During the summer of 1953, cone growth, terminal growth, flowering, and cone damage by insects were recorded periodically on tagged branches of selected trees near Angus, Ontario. These events are portrayed graphically in Fig. 1.

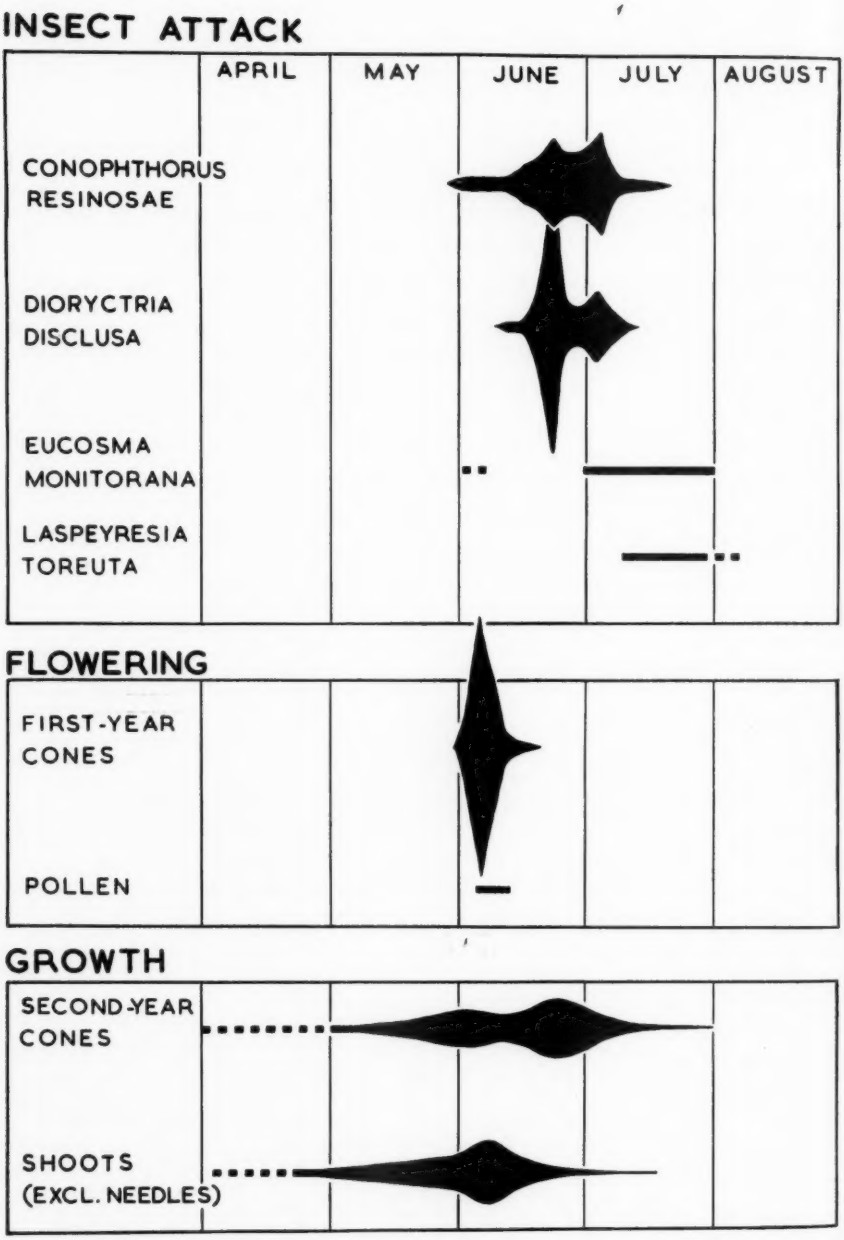

Fig. 1. Time and duration of cone attacks by insects in relation to red pine flowering and growth of cones and shoots, Camp Borden, 1953.

Where the records for some events are inadequate, duration is shown as a simple or broken line. Cone damage by *Dioryctria cambiicola* and *Rubsaamenia* sp. is omitted, since populations of these insects were too low to permit accurate records. However, on the basis of other observations, damage by *D. cambiicola* occurred about a week after that by *D. disclusa*, and maggots of *Rubsaamenia* sp. could be found in cones beginning in early June. *D. abietella* was not present in the study trees, but in other years, larvae of this species were found in cones throughout June, July, and August.

In general, damaging of cones by insects was almost completely confined to June and July, with most intense damage occurring between mid-June and mid-July. This agrees substantially with observations in previous years but would not be true if *D. abietella* were present, since this insect continues to damage cones until later in the summer.

The extremely sharp peak of cone attack by *D. disclusa* seems to be associated with the time of pollen release. Young larvae of this species feed in maturing male flowers of red pine but later migrate to and attack second-year cones as semi-mature larvae (3). The second peak of damage, in early July, probably reflects the movement of larvae to fresh cones.

The date of first cone attack by *Eucosma monitorana* was uncertain, because newly infested cones contained only minute larval entrance holes, which were easily overlooked, and did not immediately begin to deteriorate. This accounts for the broken line in early June in Fig. 1. Cone attack by fourth- and fifth-instar larvae, which occurred from late June onward, was easily recognizable.

Damage by *Laspeyresia toreuta* was not recorded directly from cones under continual observation, because the larval entrance holes were visible only with the aid of a dissecting microscope. This information was obtained from examination of cones collected periodically from nearby trees and supports the opinion held previously (4) that cone attack by this species is deferred until second-year cones have nearly reached their full size. Cone attack by *L. toreuta* does not begin until that by *C. resinosae* and *D. disclusa* is virtually complete, and the destruction of seeds in infected cones continues into August.

Two phases in the elongation of second-year cones (Fig. 1) are apparent in the growth record of individual cones, and confirm similar observations made at Sault Ste. Marie in 1951. A reasonable explanation of this pattern is that cone growth is homologous with that of vegetative terminals, in which case the two phases of growth in cones are probably an early elongation of the cone axis, followed by elongation of the distal scales. Only the first of the comparable phases in the growth of terminals is shown in Fig. 1. However, the elongation of distal needles increases the length of the terminal in the same way that elongation of distal scales increases the length of the cone. Needle elongation reached its maximum near the time of completion of shoot elongation and continued well into August, long after the cessation of cone growth.

Intensity of Insect Damage to Cones

Almost all insect damage to red pine cones occurs during the second or final year of cone development, although a few cones are killed, directly or indirectly, during their first year. Damage usually brings about death of the cone within a few weeks. Infestation by *C. resinosae*, and *E. monitorana*, invariably kills the cone, but damage by *Dioryctria* spp. and *Rubsaamenia* sp. may occasionally be light enough to permit the cone to recover. With these insects, therefore, seed loss is generally equivalent to cone damage. In the case of infestation by *L. toreuta*, however, growth and development of the cone is unimpaired, the larvae

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TABLE I
Percentage of Damage to Red Pine Cones by Insects
In the Order of Their Importance, 1950–1954

Locality	1950	1951	1952	1953	1954
Camp Borden	+57 bafe	−100 b*	+70 abe	+ 32 baef	−89 abef
Midhurst	–	–	+40 Abfdec	+ 61 Abe	−90 Abfced
Rainwick School (15 miles from Camp Borden)	+86 bad	+ 34 bad	−87 bda	+ 66 badf	−88 badf
Chalk River	+16 Abef	− 75 Abcef	−96 Abcfe	–	–
Sault Ste. Marie	+94 Aebcf	+ 70 Abe	−87 Abe	−100 Ae	+76 Ace
Lake Kipawa	+11 (b?)e	− 5 (b?)e	− 0	–	–

a = *Conophthorus resinosae* Hopk., b = *Dioryctria disclusa Hein.*, c = *D. abietella* (D. and S.), d = *Eucosma monitorana* Hein., e = *Laspeyresia toreuta* Grt., f = *Rubsaamenia* sp.,
A = almost all damage by *C. resinosae*.
*very small cone sample.
+ and − indicate whether cone crop was larger or smaller than that of previous year.

seldom destroying all the seeds, and cone damage is consequently not equivalent to seed loss. There is thus a tendency, when assessing damage by insects, to overestimate seed loss, if cones infested by *L. toreuta* are treated as though all the seeds were destroyed. However, the error introduced in this way is negligible, since infestation by this species is always light.

Almost all the trees used for sampling cone damage were open-grown, and ranged in height from 15 to 45 feet. Larger trees in closed stands were excluded because the cones were inaccessible. Wherever possible, the same trees or groups of trees were sampled each year. In most stands cone sampling was carried out late in the summer, after the insects had left the cones. The number of cones per sample varied from about a dozen to more than 100, depending on the abundance and accessibility of the cones and on the variability of damage within the tree.

Table I summarizes estimates of the intensity of insect damage to second-year red pine cones in the main sampling localities for the period 1950 to 1954. The lettered annotations beneath each estimate indicate the insects responsible for the damage, ranked in the order of their importance. The plus and minus signs indicate in a general way whether the crop of second-year cones was larger or smaller than that of the previous year.

The large differences in cone damage from year to year in the same locality, evident in Table I, arose in part as a natural consequence of the change in the level on cone production. Since relative cone damage depends on the abundance of cones, which fluctuates from year to year, it is not surprising to find in Table I that damage decreased when cone production increased (six cases out of seven), and increased when cone production decreased (nine cases out of 11). The fact that the cone-damaging insects are generally restricted to cones probably accounts for this relationship.

Fluctuations in cone production also seem to be important in the natural control of cone insects in red pine. When insect density is low, different species

TABLE II
Insect Damage to Red Pine Cones in Ontario, 1954

Locality	Percentage of cones damaged	Percentage of cones damaged by:					
		C. resinosae	*D. disclusa*	*D. abietella*	*E. monitorana*	*L. torcula*	*Rubsamenia* sp.
Lake Simcoe District							
Simcoe County							
Midhurst (A)	90	58	6	6	4	10	16
Midhurst (B)	90	87	9	2	–	1	1
Angus	heavy	5	70	3	3	16	3
Thunder Bay	50	67	–	–	–	7	26
Stayner	50	28	10	45	–	–	17
Tosorontio Tp.	70	54	13	33	–	–	–
York County							
Whitechurch Tp.	90	–	–	84	–	–	16
Parry Sound District							
Dorset	80	61	–	30	–	–	9
Britt	90	100	–	–	–	–	–
Rosseau Rd.	90	67	–	–	–	–	33
Loring	unknown	64	–	36	–	–	–
Trout Creek	90	–	–	57	–	–	43
Sudbury District							
Allan Tp.	10	100	–	–	–	–	–
Pembroke District							
Golden Lake	unknown	77	13	5	–	–	5
Sault Ste. Marie District							
Waugush Lake	unknown	100	–	–	–	–	–
Thessalon	20	–	–	0	61	–	39
Pte. aux Pins	80	99	–	1	–	–	–

– = not present;
0 = present but not adding to injury.

seldom occupy the same cones; however, when density is high, and this situation occurs when cone production decreases from a higher previous level or when the insects increase during cone abundance, different insects more often occupy the same cones, and the resulting competition may be extremely detrimental. For example, in 1952, among trees about 40 miles west of Pembroke, more than half of the cones infested by *C. resinosae* were also occupied by *E. monitorana*. Mortality of *C. resinosae* was about 20% in cones in which it occurred alone, but almost complete in cones that also contained *E. monitorana*. Most *C. resinosae* larvae probably perished from starvation, but some may have been preyed upon by *E. monitorana*.

Table I shows further that there was little change in the species composition of the infestations from year to year. At three locations, Midhurst, Chalk River, and Sault Ste. Marie, the cone beetle, *C. resinosae*, was by far the most abundant cone insect in all years, while *D. disclusa* was most common at Camp Borden and Rainwick School.

More extensive information on insect damage to red pine cones became

TABLE III
Damage to Red Pine Cones by Insects at Camp Borden, 1953

Tree No.	Percentage of cones damaged	Percentage of cones damaged by:			
		C. resinosae	*D. disclusa*	*L. toreuta*	*Rubsaamenia* sp.
1	40	56	28	0	16
2	50	22	66	6	6
3	30	0	39	61	0
4	20	0	100	0	0
5	60	0	21	76	3
6	20	60	40	0	0
7	40	0	47	47	6
8	20	6	12	41	41

available in 1954 through the cooperation of the Forest Insect Survey, Sault Ste. Marie. This is shown in Table II, which points up the variability, even within one locality, e.g. Simcoe County, in the relative abundance of different insects, and emphasizes some of the features that were brought out in Table I. *C. resinosae* tended to dominate cone damage, sometimes to the complete exclusion of other insects. During 1954 the cone beetle was absent from only three of 17 cone samples, and where present, was of first importance in all but two. *D. abietella* was scarce during the first few years of the investigation, but in 1954 was almost as common, though not so destructive, as *C. resinosae*. *D. disclusa* was virtually limited to Simcoe County, while *E. monitorana* was abundant only at Thessalon in the Sault Ste. Marie District.

There is often great variability in both the cause and intensity of cone damage on trees that are quite close together. An example of this is shown in Table III, which records cone damage for eight trees of mixed age at Camp Borden in 1953. Although all eight trees were within a 50-yard radius, cones on only two trees were infested by all four species, and on one by only one species. No explanation can be offered for the variability in damage to the cones or in the species of insects present in these trees.

Discussion

The estimates of damage given in this paper amply demonstrate the important role of cone insects in seed production of red pines in Ontario. Although the data do not cover all localities, they do emphasize that almost complete destruction of cone crops for several successive years is not unusual. These investigations cover only a small part of the "cycle" of cone production in red pine, so it is not possible to assess the long-term effect of cone insects on seed yield. However, the relative intensity of damage has been shown to vary inversely with fluctuation in cone production, i.e., the intensity of damage increases following a decrease in cone production, and vice versa. The effect of cone production on the insects themselves is also apparent. A decrease in cone abundance may result in competition between different insects, which is detrimental to some, if not all, species.

Some insects seem to be less successful than others in such competition, owing to their particular biology and to natural control factors. Thus, *L. toreuta* is at a disadvantage in comparison with other species, in that it attacks cones later in the summer and requires fresh cones for its development. A severe shortage of cones is likely to be most detrimental to this species, since other insects may have destroyed all the available cones earlier in the summer. On the other hand, *L. toreuta* is apparently the only red pine cone insect that can remain dormant for two years, thus avoiding local extinction during a poor cone year (4). In contrast, the cone beetle, *C. resinosae*, notwithstanding its low reproductive potential (2), is well fitted to the cone habitat, since it is usually the first species to enter cones in the spring, and can rapidly render the cone unsuitable for other insects. In addition, *C. resinosae* seems to be rather immune to parasitism (2). *E. monitorana*, *Dioryctria* spp., and other red pine cone insects fall somewhere between the above two extremes. They usually enter cones later in the season than *C. resinosae*, and sometimes suffer heavy mortality from parasitism (3, 4).

Acknowledgments

The assistance of Mr. W. R. Fassold during the field season of 1953, and the helpful criticisms of the staff of the Forest Insect Laboratory, Sault Ste. Marie, in the preparation of this paper, are gratefully acknowledged.

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Errata

Vol. LXXXVIII; p. 685: the caption under Figure 2 refers to the cut above Figure 3; the caption under Figure 3 refers to the cut above Figure 2.

Vol. LXXXIX; p. 148: in the caption for "Upper", read "Lower"; for "Lower", read "Upper".

Differences in Survival of the Wheat Stem Sawfly, *Cephus cinctus* Nort. (Hymenoptera: Cephidae), from Two Geographic Areas in Varieties of Spring Wheat[1]

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The larva of the wheat stem sawfly, *Cephus cinctus* Nort., lives inside the host stem, cuts it off at ground level in late summer, and spends the winter inside the stub below ground level. This insect can be controlled by the use of resistant spring wheats such as Rescue and Golden Ball. The possibility of the existence of a strain of *C. cinctus* to which these varieties are not resistant is of major importance.

Platt, Farstad, and Callenbach (1948) found that the average percentages of Rescue stems cut by *C. cinctus* for five years were 36 at Regina, Saskatchewan, and two at Lethbridge. They suggested that this difference may have resulted from the effects of the environments in two areas, or from genetic variations between the sawflies at the two stations.

The present study was undertaken to determine if the sawflies from Lethbridge and Regina differed in their abilities to infest and cut Rescue and other varieties of spring wheat.

Materials and Methods

The experiments were done at Lethbridge from 1949 to 1953 and duplicated at Regina in 1952 and 1953. Each variety was planted in a solid block and divided into randomized plots, of which equal numbers were infested with sawflies from Thatcher wheat collected from Regina and from Lethbridge. Each plot was covered during the sawfly flight period with a plastic screen cage, two feet square and three feet high. In 1949, adults that emerged in the laboratory from stubs collected in the spring were used to infest the plots. In 1950, 1951, and 1952, 100 stubs containing larvae were collected in the spring and buried in each plot; for the test in 1953, they were collected the previous fall, stored in the laboratory until spring, then buried in the plots.

The mature host plants were examined for infestation and for cutting, and in 1953 for tunnelling as well. Stems containing parasitized larvae were counted as cut.

As there were only two replicates per treatment in 1949, 1950, and 1951, the data for those years were not analyzed statistically. The data from the treatments in 1952 and 1953, which were replicated four and eight times respectively, were converted by the angular transformation, and subjected to Student's *t* test for unpaired samples (Cox, 1954).

The spring wheats used were: the hollow-stemmed susceptible bread wheats Red Bobs and Thatcher; the solid-stemmed, resistant bread wheat Rescue; and the solid-stemmed, resistant durum wheat Golden Ball. Rescue and Golden Ball were used in 1949 and 1952, all four varieties were used in 1950 and 1951, and Golden Ball alone was used in 1953.

Results

There were no apparent differences between the two groups of sawflies in infestation and cutting of Red Bobs and Thatcher in 1950 or 1951. The two-year average percentages were:—

[1]Contribution No. 3502, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada; from a thesis submitted by the senior author in partial fulfilment of the requirements for the Ph.D. degree, Oregon State College, 1954.

[2]Entomologist, Assistant Entomologist, and Associate Entomologist.

	Variety	Source of sawflies	
		Lethbridge	Regina
Stems infested	Red Bobs	90	94
	Thatcher	79	86
Infested stems cut	Red Bobs	77	77
	Thatcher	71	77

The data from Rescue for 1951 showed no significant difference between the Regina and Lethbridge sawflies in either the percentages of stems infested or in the percentages of infested stems cut (Table I).

TABLE I

Percentages of stems infested and of infested stems cut in two varieties of wheat by sawflies from two localities

Year	Station	Source of sawflies	Golden Ball		Rescue	
			Stems infested	Infested stems cut	Stems infested	Infested stems cut
1949	Lethbridge	Lethbridge	56	17	40	5
		Regina	52	7	88	3
1950	Lethbridge	Lethbridge	93	56	89	12
		Regina	94	28	94	16
1951	Lethbridge	Lethbridge	72	27	76	74
		Regina	77	15	91	81
1952	Lethbridge	Lethbridge	94	77*	95	72
		Regina	90	66	90	63
	Regina	Lethbridge	78	17	65	11
		Regina	68	11	67	13
1953	Lethbridge	Lethbridge	94	31**	–	–
		Regina	94	16	–	–
	Regina	Lethbridge	71	37**	–	–
		Regina	57	16	–	–
	Average	Lethbridge	78	44	89	44
		Regina	74	27	85	37

*Significant at 5% level.
**Significant at 1% level.

Although the two groups did not differ significantly in percentage infestation of Golden Ball in either 1951 or 1952 (Table I), the trend for the Lethbridge sawflies to cut higher percentage of infested stems was consistent for every test. At Lethbridge in 1952 and at both stations in 1953, the Lethbridge sawflies cut a significantly higher percentage of infested stems of Golden Ball than did the Regina sawflies.

The percentages of infested stems of Golden Ball tunnelled and of tunnelled stems cut in 1953 were:

Station	Source of sawflies	Infested stems tunnelled	Tunnelled stems cut
Lethbridge	Lethbridge	62**	50
	Regina	33	50
Regina	Lethbridge	81*	46*
	Regina	58	28

*Significant at 5% level.
**Significant at 1% level.

A major difference between the two groups of sawflies in Golden Ball in 1953 at both stations was the significantly higher percentage of infested stems tunnelled by the larvae of the Lethbridge sawflies. Also at Regina, though not at Lethbridge, the percentage of tunnelled stems cut was significantly higher for the Lethbridge sawflies.

Discussion

The effect of environment in reducing host-resistance to *C. cinctus* is shown by the data for Rescue for 1951 and 1952 at Lethbridge, and for Golden Ball at Lethbridge in 1950 and 1952 (Table I). Such an effect evidently resulted in the differences in cutting of Rescue wheat at Lethbridge and Regina observed by Platt, *et al.* (1948). However, the two groups of sawflies do appear to differ genetically as shown by the differences in cutting of Golden Ball. It is possible that these differences occurred because the Lethbridge and Regina sawflies were grown in their respective localities the generation preceding each test. Variety of host was the same for both groups of sawflies.

Farstad, Platt, and McBean (in preparation) found that, in 1944, females of *C. cinctus* from Regina were longer and contained more eggs than those from the same host variety from Nobleford, Alberta. They considered that these differences resulted from the effects of the weather on the host plants; in 1943, dry weather at Nobleford resulted in small, thin stems while adequate moisture at Regina produced large, thick stems. However, during the five years of the tests described here, as the moisture was adequate in both areas such differences in the fecundity of females from the two regions would not be expected. If the females from the two areas had differed in fecundity, these differences should have been shown by differences in the percentage of stems that they infested. This was not the case. Moreover, if a difference in the number of eggs per infested stem had resulted in the difference between the two groups of sawflies in cutting of Golden Ball, the differences in cutting should also have occurred in Rescue and the other varieties tested.

Summary

The percentages of infested Rescue stems cut by the wheat stem sawfly from Regina and Lethbridge did not differ significantly; hence the difference previously observed in the cutting of Rescue wheat by *Cephus cinctus* Nort. at the two localities must have been the result of environmental differences. However, the two groups of sawflies did differ significantly in the percentages of infested stems cut in the durum variety Golden Ball. The higher percentage of stems of Golden Ball cut by the Lethbridge sawflies apparently resulted from genetic differences between the sawflies from the two localities. The percentage of Golden Ball stems in which larvae became established was significantly higher for the Lethbridge group than for the Regina group. In addition, in 1953 at Regina,

the percentage of stems in which established larvae reached maturity was significantly higher for the Lethbridge sawflies than for the Regina sawflies.

Acknowledgments

The authors acknowledge their appreciation to Drs. C. W. Farstad, R. W. Salt, and G. A. Hobbs of the Lethbridge laboratory for guidance in the studies and criticisms of the manuscript.

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Elm Bark Beetles in Southwestern Ontario[1]

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Introduction

The Dutch elm disease is caused by the fungus *Ceratostomella ulmi* (Schwartz) Buis. It was first reported in the United States at Cleveland, Ohio, in 1930 (11), and has since spread westward to Colorado and northeastward into Vermont (22). It is believed that the disease was accidentally introduced into the United States from Europe, where it has caused heavy mortality of elms since its discovery in 1919 (7, 19, 20). In Canada the disease was first recorded by Pomerleau (14) at St. Ours, Que. This infection proved to be centred around Sorel, Que., and since it was isolated from the nearest known infection in the United States by approximately 200 miles, is regarded as a separate introduction from Europe. The Sorel infection spread very rapidly, and by the end of 1950, the area between Montreal, Quebec City, and Sherbrooke was heavily infested by the fungus (17). It has since spread westward as far as Ottawa and Kingston in Ontario (16).

During the summer of 1950, a new centre of infection was discovered in Essex County in southwestern Ontario. The large number of infected trees found at this time in a relatively small area suggests that the disease had been present for a considerable time before its discovery. It seems likely that this infection had its origin in the neighbouring States of Michigan and Ohio. The disease has spread slowly from Essex County in a northeast direction and now extends to a line drawn roughly from Sarnia, through London, to Toronto (16).

Two elm bark beetles are the principal vectors of the Dutch elm disease in North America. The smaller European elm bark beetle, *Scolytus multistriatus* (Marsh.), is a species introduced from Europe. It was first reported in the United States near Boston, Mass., in 1909 (2), and has since been found in most of the States east of the Mississippi River, in Missouri, Arkansas, Louisiana, Oklahoma, Colorado, and California, and in Ontario (25). It was reported for the first time in Canada in Essex and Kent Counties in southwestern Ontario in 1948 (24). Presumably the beetle entered Ontario from the State of Michigan, where it had been known since 1946. It is significant that this insect vector was found in southwestern Ontario two years in advance of the discovery of the

[1]Contribution No. 345, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada.

disease. Its present distribution in Ontario is roughly south of a line drawn from Sarnia to Hamilton.

The native elm bark beetle, *Hylurgopinus rufipes* (Eichh.), is indigenous to North America, and its distribution corresponds closely to that of its host trees –the elms, *Ulmus* spp. In the United States it occurs from the Canadian border south to Kentucky and Virginia and west to Missouri (1). In Canada, the author has observed this species at widely separated localities in southern Ontario and southern Quebec and also in the vicinity of Fredericton, N.B.

Since the Dutch elm disease is largely dependent on bark beetles for its transmission from diseased to healthy trees (4), controlling the beetle population is a logical indirect method of controlling the disease. The most effective way of reducing the beetle population is through sanitation practices combined with the application of suitable insecticides (12, 25). The efficacy of insecticides is dependent on the time of application in relation to the seasonal history of the beetles. It is, therefore, necessary to understand fully the seasonal history and habits of the beetles in the area where the control is to be applied, in order to obtain the greatest success.

Data on the seasonal history of *S. multistriatus* were obtained from 14 healthy elm trees, *Ulmus americana* L., cut and set up as trap logs at two-week intervals during the latter half of the 1953 season and throughout the 1954 season. The trees ranged from 3 to 5 inches in diameter and were free of wounds and dead limbs. The trunks were cut into 3-foot sections and placed horizontally on racks so that they were supported approximately one foot from the ground. All the racks were placed in partial shade since Martin (10) reported that this was the best condition for infestation.

Each set of trap logs was sampled and brood development recorded daily during the first week of attack and weekly thereafter until pupae began to form under the bark. At this time the logs were placed in outdoor screen cages until the first adult emerged and then in rearing cans for the final emergence period. General brood development on standing trees in the field was observed as a check on possible faulty rearing technique.

In the Windsor area, *H. rufipes* occurs in such small numbers that it was necessary to establish plots north of London and Sarnia in order to have a sufficiently high beetle population to work with. The data presented here are based on examination of seven healthy elm trees cut at two-week intervals from mid-May to September in 1954. These trees, measuring from 4 to 6 inches in diameter, were cut into 3-foot logs, which were placed on racks a foot above the ground in deep shade. At two-week intervals, 1-foot samples were taken from each set of trap logs and records were kept of the attack pattern and brood development. When the pupal stage was reached the logs were treated in the same manner as described above in the study of *S. multistriatus*.

Seasonal History and Habits of *Scolytus multistriatus* (Marsh.)

The seasonal history of *S. multistriatus* in southwestern Ontario differs to some extent from that reported in the eastern United States. Collins *et al.* (3), Jones (8), Wallace (23), and Welch *et al.* (26) report two and a partial third generations per year. In southwestern Ontario, it was found that there is only one full generation, with a partial second generation, little of which overwinters successfully. The insect overwinters in the larval stage, giving rise to adults in June and July (summer adults). Most of the progeny of these summer adults emerge in August and early September (autumn adults), although some do not complete development by autumn but overwinter as larvae giving rise to the

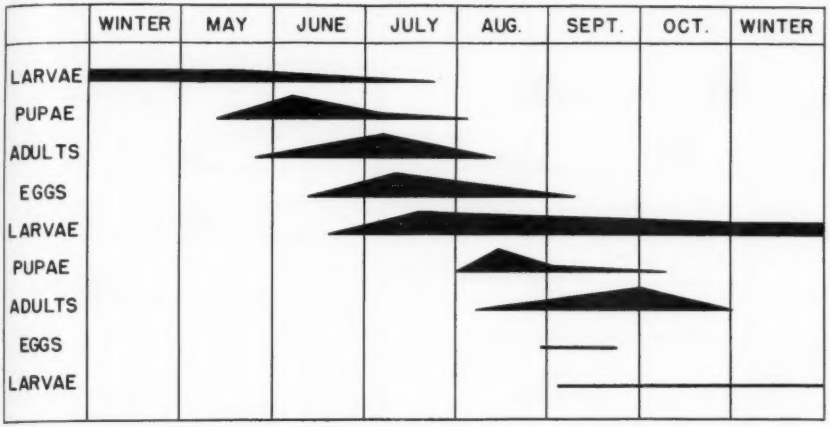

Fig. 1. Seasonal history of *Scolytus multistriatus* (Marsh.) in southwestern Ontario.

bulk of the next summer's adults. Only a few of the earliest autumn adults to emerge successfully construct brood galleries and give rise to overwintering larvae. The remainder feed in the crotches and bark of elms for about one month and then die with the approach of cold weather without constructing brood galleries. Peak adult attack occurs during late June and early July. Fig. 1 illustrates the seasonal history of the beetles in southwestern Ontario, and Fig. 2 the relationship between adult attack and emergence.

In studying *S. multistriatus* in the Windsor area, there were no significant differences noted in its habits from those reported in the New England States (3, 8, 25).

Seasonal History and Habits of *Hylurgopinus rufipes* (Eichh.)

The seasonal history of *H. rufipes* does not differ in southwestern Ontario from that in Quebec (6, 18) nor that in the New England States (9). Beetle activity begins about two weeks earlier in southwestern Ontario than in Quebec, but this has no effect on the number of generations per year since the longer season is absorbed by a lengthened feeding period in the autumn.

The data obtained in southwestern Ontario show that there is one full generation plus a partial second generation per year. The main population overwinters in the adult stage, emerges from hibernation tunnels in early May, and constructs brood galleries and oviposits during May, June, and July, giving rise to first adults in late July. The new adults feed in the bark of healthy elms until late in September and then overwinter in hibernation tunnels. A few of the more advanced adults of the new generation construct brood galleries in September, giving rise to overwintering larvae. These larvae, together with a small number of retarded spring larvae and some summer larvae, constitute a small percentage of the total overwintering population. The overwintered larvae give rise to adults in June and these adults construct brood galleries and oviposit in July and usually develop to adults by early September. Peak adult attack occurs during May and June. The seasonal history is illustrated in Fig. 3, and the relationship between adult attack and emergence in Fig. 2.

The habits of *H. rufipes* in southwestern Ontario are similar to those in Quebec and the New England States. The time of flight in the spring and the

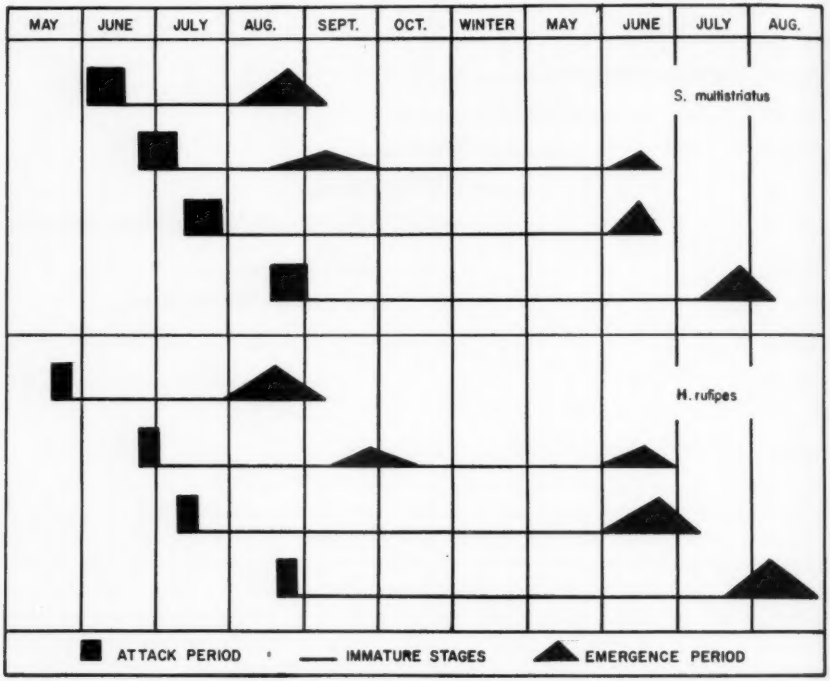

Fig. 2. Relation between adult attack and emergence periods of *Scolytus multistriatus* (Marsh.) and *Hylurgopinus rufipes* (Eichh.) in southwestern Ontario.

length of the feeding period in the fall vary with the local climate, but the breeding and overwintering habits are similar in the three locations.

Discussion

In the absence of the Dutch elm disease, neither *S. multistriatus* nor *H. rufipes* is of economic importance, since they are found in small numbers and attack only decadent or dying elm trees. Together with the disease, however, the beetle population builds up to very large numbers. When both species are present, *S. multistriatus*, being considerably more aggressive than *H. rufipes*, invades available breeding material more readily, and limits the *H. rufipes* population to relatively small numbers (3, 4). For this reason, as well as the fact that it feeds (and thereby transmits the disease) in a more spectacular manner than *H. rufipes*, *S. multistriatus* is generally accepted in the United States as the more important vector of the Dutch elm disease (4, 5, 22). It should be kept in mind, however, that in Quebec, where *H. rufipes* is the only known vector of the disease, the disease became very severe over a large area in a relatively short period of time. It is the author's opinion that *H. rufipes* is greatly underestimated as a vector of the Dutch elm disease. Adults of *H. rufipes* are active in the field nearly one month earlier than adults of *S. multistriatus* (Fig. 2), and from a pathological point of view this is important, since the inoculation of healthy trees with the Dutch elm disease by bark beetles is confined almost completely to the spring and early summer season (13, 15, 21, 27). It is, therefore, suggested that due

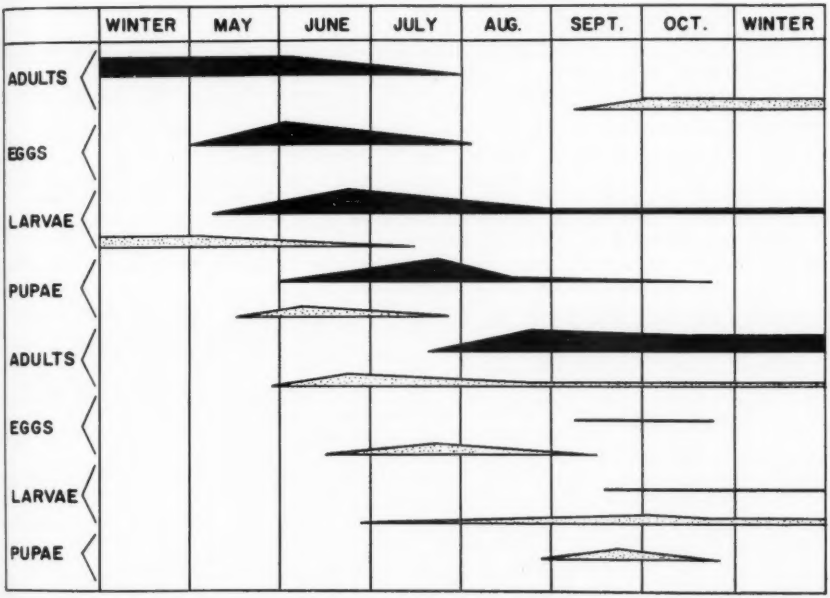

Fig. 3. Seasonal history of *Hylurgopinus rufipes* (Eichh.) in southwestern Ontario.

consideration be given to this species when planning control programs, even when it is largely outnumbered by *S. multistriatus*.

The relationship between attack period and adult emergence must also be considered in applying insecticides to control the beetle vectors. In Fig. 2, it is clear that broods established early in the summer may be killed on emergence as adults by insecticides applied the same year, but that broods established late in the summer can be most effectively controlled throughout the summer following attack.

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(Received January 21, 1957)

Improved Technique for Inflating and Mounting Insect Larvae[1]

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A collection of pinned, inflated larvae systematically arranged in Schmitt boxes provides an invaluable reference for taxonomists. Inflated or blown larvae are more readily available for examination and usually retain their colours better than do "liquid-preserved" larvae. Inflation has disadvantages in that the specimens are more easily damaged and require more time in preparation. However the importance of these two factors has been reduced by techniques employed at the Vernon Laboratory.

Equipment

Infra-red reflector lamp (250 watt), preferably with ruby-red glass and nickel reflector, clamped upright to desk with photographer's reflector clamp (Fig. 1); inflating ball and tube; tubular glass rod; fine pointed tweezers; dissecting scalpel; glass tubes drawn to a point; clamps and rubber tube to hold clamps (Fig. 2); glycerine; insect pins and "straight elbow pins".

Method of inflating larva

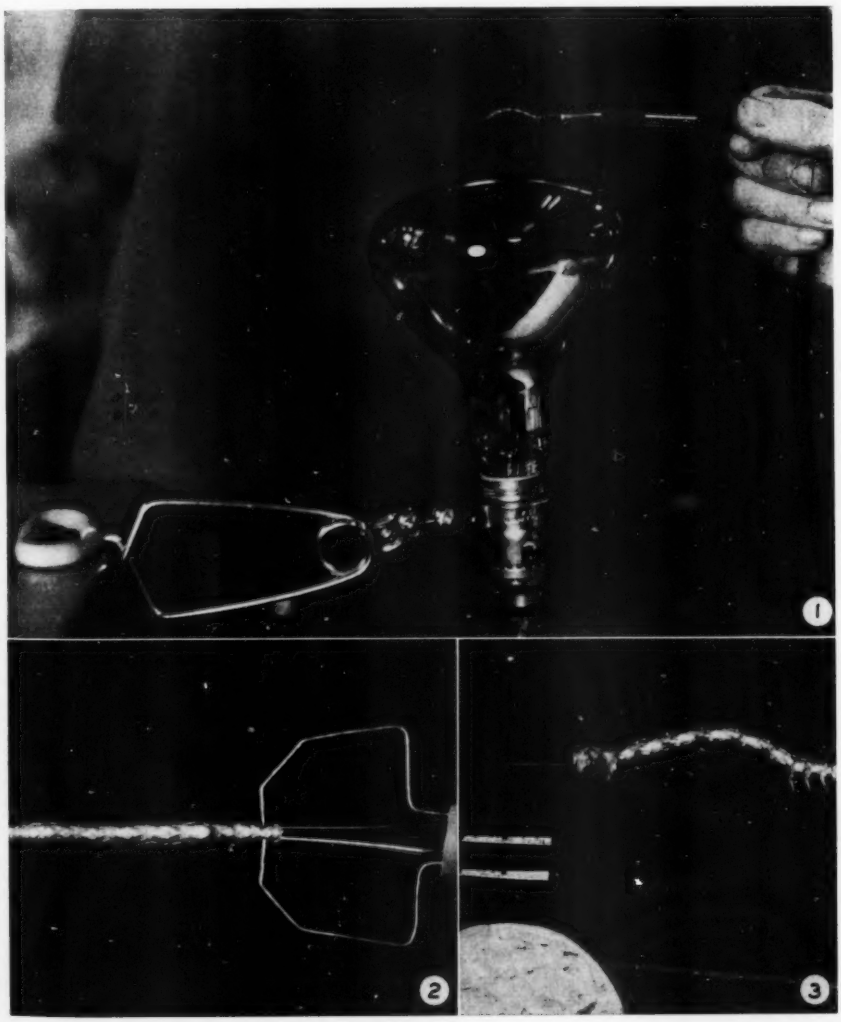
1. The larva should be starved for 24 hours to simplify extraction of the gut and to prevent discoloration by food in the alimentary tract. Place the living larva on a blotter and with a microscalpel puncture the wall of the hind gut through the anus while the larva is held flat on the blotter.

[1]Contribution No. 343, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada.

2. With a medium to small larva, insert tweezers into the anus and extract the gut in one piece leaving the body juices inside to retain the natural colour of the larva.

For a larger larva it is necessary to apply pressure with the glass tube, rolling from the head to the anus. Repeat until all the body fats are removed. Be careful not to squeeze the colour out of the integument. The blotter will absorb the body fluids that escape.

A larva with numerous or fragile setae requires different treatment. Keep the living larva at 32°F. for 5 minutes to make the larva limp and to ensure that



Figs. 1-3. 1, drying larva over infra-red lamp; 2, larva clamped to glass tube; 3, inflated larva on larval mount pin.

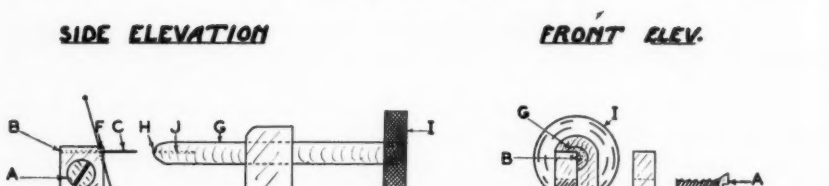


FIG. 4.

FIG. 5. 1 INCH

LEGEND
A. VICE SCREW
B. 1/64" CIRCULAR SLOT FOR GUIDE PIN
C. GUIDE PIN
D. DOWEL
E. VICE JAW
F. 1/32" SQUARE SLOT
G. TWISTING ROD
H. CASE HARDENED NIPPLE
I. KNOB OF TWISTING ROD
J. FEMALE SOCKET FOR GUIDE PIN

Figs. 4-5 Instrument for making inflated larval mounts; 5, larval mount pin.

movement will not dislodge or damage the setae. Place a 1-inch-square of wax paper over the larva and exert a little pressure with the forefinger rather than the glass rod to reduce the possibility of flattening, breaking or dislodging the setae. Extract the gut slowly so that the blotter may readily absorb the body juices, thus keeping the setae dry.

3. Rub a minute amount of glycerine on to the tip of the glass tube; remove the excess by rolling the tip of the glass on a clean blotter. Insert the tip of the tube into the anal opening about 1/32 to 1/16 of an inch. Place the clamps on the spiracular lines of the larva just in front of the anal prolegs securing the integument to the glass tube.

4. Inflate the larva with the ball and tube apparatus. Do not stretch the larval integument excessively; attempt to keep it as close to its natural size as is feasible.

5. Hold the inflated larva about 2 inches above the centre of the infra-red lamp, rotating the specimen so that the integument may harden evenly. Dry until the head and thorax are rigid to the touch. They are the last to harden.

6. Gently remove the clamps and tease the inflated specimen from the glass tube. The glycerine should keep the larva from sticking to the glass.

Method of mounting inflated larva

Insert a number 3 insect pin through a larval mount pin (straight elbow pin) ranging in size from 00 to 1 depending on the size of the larva. Rub a small amount of glue along the underside of the larval mount pin and insert it ¼ to ½ inch through the anus, gluing the inside of the venter to the pin (Fig. 3).

The larval mount pins have the following advantages over other double mount methods: the method is quicker, larvae so mounted take up less room,

look neater, and do not break as readily if accidentally touched or if the display box is jarred.

Instrument for Making Inflated Larval Mounts

The commercial manufacture of "straight elbow pins" has been discontinued, consequently a simple steel instrument was designed by the writer for mass producing them.The instrument is illustrated in Figure 4. Instructions for its use follow:

1. Loosen vice screw (A), place a ⅞ inch length of a number two pin in the slot (B), with ⅜ inch of the pin protruding. This will serve as a permanent guide pin (C). Tighten the vice screw. This and the dowel (D) hold the vice jaw (E) firm.
2. Hold an insect pin in slot (F) with the left hand.
3. Slide the twisting rod (G) over the guide pin.
4. Catch nipple (H), at the end of the rod, on the mount pin and exert a slight horizontal pressure while turning the rod two complete revolutions.
5. Pull the twisting rod back, remove the mount pin and cut it off just above the coil (Fig. 5). The mount pin is then ready for use.

Reference

Ross, D. A., and J. K. Harvey. 1954. Note on Infra-red Lamp for Drying Inflated Larvae. *Can. Ent.* 86: 158.

Some New Genera and Species of North American Cerambycidae (Coleoptera)

By E. Gorton Linsley
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Elaphidionoides Linsley, new genus

Hypermallus Casey (not Lacordaire), 1912, Mem. Coleopt. vol. 3, p. 292.

Form elongate, slender to moderately robust, subcylindrical to moderately depressed. Head narrowly channeled between antennal bases; maxillary and labial palpi short, not very unequal, last segment slightly expanded; antennae moderately heavy, outer segments more or less flattened, often convex or carinate, third segment armed at inner apex with a moderate spine, those of following segments, if present, becoming successively shorter, outer angle of segments mute or armed with a small spine. Pronotum subcylindrical or rounded at the sides, usually with dorsal tubercles or calluses; prosternum with intercoxal process arcuately declivous behind; episternum of metathorax narrow, nearly parallel-sided. Elytra with apices usually emarginate, usually bispinose. Legs slender; femora without apical spines.

Type species: *Stenocorus villosus* Fabricius

Elaphidionoides is proposed for the group assigned by Casey (1912) to *Hypermallus* Lacordaire. However, Lacordaire (1869) designated *Cerambyx pulverulentus* De Geer, 1775 (=*C. atomarius* Drury, 1773) as the genotype, making the name synonymous with *Enaphalodes* Haldeman (1847) and *Romaleum* White (1855).

This genus differs from *Elaphidion* by having the intercoxal process of the prosternum arcuately declivous behind rather than abruptly, vertically or concavely declivous, the femora unarmed at the apex, and the spine of the third antennal segment moderate.

Micraneflus Linsley, new genus

Form elongate, subcylindrical, a little robust. Head moderately impressed between antennal tubercles; eyes coarsely facetted; maxillary and labial palpi very unequal, last segment only feebly expanded; antennae eleven-segmented, surpassing elytral apices in the male, a little shorter than the body in the female, segments without apical spines, dorsal carinae evanescent or lacking, outer segments slightly produced externally but not serrate. Pronotum coarsely, closely punctate with a median longitudinal subbasal smooth area; prosternum with intercoxal process very narrow, apex only slightly expanded, coxal cavities open behind by much more than apical width of process; episterna of metathorax moderately narrow. Elytra with apices rounded externally, suture with a stout tooth. Legs slender; femora not clavate; tibiae obsoletely carinate.

Type species: *Aneflomorpha imbellis* Casey

This genus is related to *Aneflomorpha* from which it differs by having the antennal segments completely unarmed. The antennae and tibiae are obsoletely carinate and the anterior coxal cavities very narrowly separated and open behind by very much more than the apical width of the intercoxae process. From *Axestinus* it differs in the more slender antennae which are eleven-segmented in both sexes and longer than the body in the male, the form of the elytral apices and the sculpturing of the pronotum.

Elaphidion clavis Linsley, new species

Female: Form elongate, moderately robust; color dark brown, dull; pronotum and elytra clothed with fine, prostrate, pale, faintly yellowish pubescence which is not conspicuously condensed into patches, elytra without an intermixture of long, erect hairs. *Head* sparsely, coarsely punctate between the eyes, more finely, densely punctate behind; antennae not attaining apex of third abdominal segment, third and fourth segments bispinose at apex, the outer spine short, segments five to ten with an inner spine at apex, outer angle more or less acute, third segment subequal to scape, one-fourth longer than third segment, segments four to ten gradually decreasing in length, eleventh segment subequal to tenth, elongate oval. *Pronotum* very coarsely punctate, with a narrow, elevated, longitudinal, smooth vitta which becomes a little broader, flat, and less clearly defined posteriorly, and a small, irregular, convex, smooth area on each side of disk in front of middle, pubescence fine, appressed, denser at sides; prosternum finely punctate with a few coarse punctures, intercoxal process prominent, apex abruptly, concavely declivous; mesosternum with intercoxal process prominent, subvertical; metasternum and episterna of metathorax finely punctate with scattered coarse punctures superimposed, moderately densely pubescent. *Elytra* coarsely punctate at base, especially in vicinity of scutellum, but the punctures less coarse than those of pronotum and rapidly becoming smaller posteriorly; pubescence short, suberect, with obscure patches of short, appressed, denser hairs; apices prominently bispinose, the outer spine longer. *Legs* slender; femora bispinose at apex but outer spine short. *Abdomen* with punctation and pubescence similar to metasternum, fifth sternite longer than fourth, rounded to apex which is shallowly emarginate. Length, 20.5 mm.

Holotype female (American Museum of Natural History), Palmetto Key, Florida, June 3-10, 1942 (C. M. Breder) and paratype female (U. S. National Museum), Georgetown, South Carolina, August 17, 1931 (O. L. Cartwright).

This species is apparently related to *E. lanatum* Chevrolat from Cuba but the pubescence is slightly ochraceous, rather than white, and the pronotum much more coarsely punctate, the discal punctures being very much larger than those at base of elytra. In *lanatum* the discal callouses are also more prominent.

Superficially *clavis* closely resembles *E. tectum* LeConte, but may be distinguished at once by the prominently bispinose antennal segments. In view of the fact that *tectum* is known only from males and *clavis* only from females it might well be suspected that they represent the two sexes of a single species. This may prove to be the case but in no species now known to me is the bispinose condition of the antennae a sexual character, and in the related *lanatum* the antennae are similarly bispinose in both males and females.

Aneflomorpha opacicornis Linsley, new species

Male: Form elongate, subcylindrical; color piceous brown; pubescence coarse, depressed, pale. *Head* coarsely, closely punctate above; antennae extending less than one full segment beyond apex of elytra, surface of third and following segments opaque, minutely and densely punctate, densely clothed with very short, fine pubescence, segments three to five spinose at apex, spine of third segment moderately stout, that of fifth segment minute but evident, carinae fine, distinct on segments three to five, faint on segments six to eight or nine, segments four to nine slightly expanded externally at apex, third segment a little longer than scape (7.5:7.0), fourth segment slightly shorter than third (7.2:7.5) fifth segment slightly longer than third (7.7:7.5), segments six to nine subequal in length, tenth a little shorter, eleventh segment longer than any of the preceding, feebly appendiculate. *Pronotum* a little longer than broad, surface coarsely, closely, but irregularly punctate except for a linear median smooth vitta which extends from a little in front of middle to basal fifth or sixth, pubescence a little denser than that of elytra; prosternum with intercoxal cavities open behind by at least width of apex of prosternal process; metasternum more or less uniformly pubescent; scent pore distinct *Elytra* three times as long as basal width; surface moderately coarsely closely punctured at base, becoming finer and sparser apically, pubescence coarse, depressed, with a sparse intermixture of erect and suberect hairs which are about as long as diameter of third antennal segment *Legs* slender; femora coarsely, closely but shallowly punctate; tibial carinae obsolete; posterior tarsi with first segment nearly as long as following two together. *Abdomen* moderately shining, shallowly punctate, clothed with depressed pubescence intermixed with erect and suberect hairs; fifth sternite apparently broadly subtruncate or shallowly emarginate at apex. Length 17.5 mm., breadth 3.8 mm.

Holotype male (U.S. National Museum) from Cline, Texas.

This species may be readily distinguished from the other known members of the genus by having the antennae beginning with the third segment opaque, densely and minutely punctate and pubescent.

Aneflomorpha luteicornis Linsley, new species

Male: Form elongate, subparallel; color brownish-testaceous, antennae, except scape, femora at base, tibiae and tarsi yellowish. *Head* coarsely, closely punctate; front feebly impressed; maxillary and labial palpi unequal, last segment scarcely expanded; antennae extending nearly two segments beyond elytral apices, segments three to six spinose at apex, spine of third segment about as long as second segment, segments three to six distinctly carinate, ciliate internally, third segment distinctly longer than fourth, a little longer than fifth, segments five to eight subequal, segments nine and ten successively shorter, eleventh segment longest, curved toward apex but not appendiculate. *Pronotum* as long as broad, sides a little obtuse behind the middle, feebly constricted at base and apex; surface coarsely, confluently, rugosely punctate except for an ill defined, narrow, median, longitudinal, impunctate callus; pubescence moderately

long, appressed, not obscuring punctation, with a sparse intermixture of long erect hairs; prosternum transversely impressed, clothed with long, appressed and suberect hairs, densely punctate behind the impression, the punctures less coarse than those of pronotum; intercoxal process expanded at apex but the angles rounded and the cavities open by as much or more than the apical width of the process; metasternum clothed with long appressed and suberect hairs. *Elytra* not quite four times as long as basal width (19:5); surface coarsely punctate but a little less so than pronotum, basal punctures close, apical punctures separated by one or two diameters, pubescence moderately long, recurved, not obscuring punctation, a few scattered, erect hairs intermixed, especially toward base and near the suture; apices obtusely rounded to the sutural angle which is spiniform. *Legs* slender; femora coarsely but shallowly punctate, clothed with appressed and suberect hairs, apex barely reaching to fourth abdominal segment; tibiae carinate, clothed with long, flying hairs. *Abdomen* shining beneath, finely punctate, clothed with long, pale appressed and suberect hairs; fifth sternite subtruncate at apex. Length, 12 mm.

Holotype male (Calif. Acad. Sci., Ent.) Mt. Washington, elev. 6,000 ft., near Nogales, Arizona, July 16, 1916 (J. A. Kusche in Van Dyke collection), and one paratype male (Van Dyke collection, Calif. Acad. Sci., Ent.) from the Huachuca Mts., Arizona.

This species agrees with *A. arizonica* Linsley, *A. parkeri* Knull, and *A. unispinosa* Casey in having the sutural angle of the elytra produced, the outer angle obtusely rounded, but it differs from all three of these in the smaller size and yellow appendages. The spine at the apex of the sixth antennal segment, evident in the type, is not visible in the paratype.

Anelaphus subinermis Linsley, new species

Male: Form elongate; integument reddish brown to brown, head and prothorax frequently darker; pubescence sparse, somewhat yellowish, variegated with patches of dense, appressed, whitish hairs. *Head* coarsely, closely punctate between and behind the eyes, without a median smooth callus behind eyes, pubescence sparse, a tuft of hairs in front of eyes, a dense lining along inner concave margin; antennae robust, tapering, extending about two segments beyond elytral apices; segments three to five distinctly and coarsely spinose at inner apex, sixth segment with a minute spine, seventh segment with inner angle acute, subspiniform, segments beginning with fourth deeply excavated and flattened externally, outer angle acute, briefly subspiniform, scape a little longer than second and third segments together, third segment longer than fourth, shorter than fifth, fifth and sixth segments subequal, segments six to ten gradually decreasing in length, eleventh segment longest, arcuate. *Pronotum* about as long as broad, sides shallowly rounded, surface opaque, finely densely punctate, the underlying coarse, shallow punctures almost completely confluent and obliterated, median discal smooth area narrow, ill defined or obsolete, anterolateral discal callosities also ill defined, densely pubescent; prosternum broadly, transversely impressed in front of coxae, punctation similar to that of pronotum, pubescence moderately dense; metasternum and metathoracic episterna finely punctate, moderately densely pubescent. *Elytra* more than two and one-half times as long as basal width, integument moderately coarsely punctate near scutellum, the punctures mostly separated by at least one diameter, becoming finer apically; apices subtruncate, sutural angle dentiform. *Legs* finely punctured and pubescent. *Abdomen* shining, finely punctate, thinly pubescent; fifth sternite shorter than fourth, broadly subtruncate or shallowly emarginate at apex. Length, 18.5 mm.

Female: Antennae reaching to fourth abdominal segment, segments three to seven with an inner apical spine; pronotum coarsely, closely punctate, the punctures larger than those of base of elytra, largest near discal callus; prosternum concave, coarsely rugosely punctate; abdomen with fifth sternite a little longer than fourth, apex broadly subtruncate, length, 17 mm.

Holotype male and allotype female from Marathon, Texas, June 5, 1940, collected by E. K. Waering (J. W. Green collection, Calif. Acad. Sciences).

This species superficially resembles *A. inermis* (Newman) (= *A. truncatum* (Haldeman)) but it is more elongate with the elytra more than two and one-half times as long as broad, clothed with shorter pubescence, and less coarsely and densely punctate at base; the median discal smooth area of the pronotum ill defined, narrow or obsolete, and the antennal segments beginning with the fourth more deeply excavated and flattened externally.

Dryobius sexnotatus Linsley, new name

Callidium 6-fasciatum Say (not *Callidium 6-fasciatum* Olivier, 1792), 1823, Jour. Acad. Nat. Sci. Phila., vol. 3, p. 415.

Callidium vandykei Linsley, new name

Callidium pallidum Van Dyke (not *Callidium pallidum* Say, 1823), 1928, Pan-Pacific Entom., vol. 4, p. 111.

Genus Callidiellum Linsley

Heyrovsky (1954) has synonymized *Callidiellum* Linsley, 1940 (type: *Semanotus cupressi* Van Dyke) with *Palaeocallidium* Plavilstshikov, 1940 (type: *Callidium coriaceum* Paykull). However, the type species of the latter is more closely related to *Semanotus*. In *Palaeocallidium* the pronotum is densely and coarsely rugosopunctate with prominent polished dorsal callosities; in *Callidiellum*, the pronotum is finely punctate with feeble tumid or impunctate areas on the disk. The species of *Palaeocallidium* are associated with fir and spruce (Pinaceae), the species of *Callidiellum* with the Cupressaceae-Taxodiaceae. *C. cupressi* (Van Dyke) breeds in *Cupressus sargentii*, *C. rufipenne* (Motschulsky) in *Cryptomeria japonica* and *Chamaecyparis obtusa*, and *C. villosulum* (Fairmaire) in *Cunninghamia lanceolata*.

Genus Meriellum Linsley, new name

Merium LeConte, 1873, Smithson. Misc. Coll., vol. 11, no. 265, p. 296.

Kirby (1873) designated *Cerambyx variabilis* Linnaeus as the type of his genus *Merium*. The above name is proposed as a substitute for the *Merium* of LeConte (type: *Callidium* (*Merium*) *proteus* Kirby).

(Received April 29, 1957)

Note on Occurrence in Cape Breton Island of *Tipula paludosa* Mg. (Diptera: Tipulidae)[1]

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In September, 1955, crane flies reared from maggots, or "leather jackets", collected from flower beds at North East Margaree, Cape Breton Island, were identified as of the Palaearctic species *Tipula paludosa* Mg. by J. R. Vockeroth, Entomology Division, Ottawa. This is probably the most injurious crane fly in Europe, where it is frequently reported in the literature as injuring grasses, cereals, beets, strawberries, hemp, flax, tobacco, and other crops. Further collecting has shown the species to be present in Murphy and Cranton sections, Inverness County, and Sydney, Cape Breton County, Cape Breton Island. It is doubtfully recorded from Newfoundland by Alexander (1942, pp. 260-261). These records constitute the only ones known in North America. *T. paludosa* was probably introduced in soil ballast dumped from ships on the shores of Cape Breton Island in the same manner as the exotic soil-inhabiting beetles referred to by Brown (1940).

Limited rearing of "leather jackets" in the laboratory produced no parasites; in Europe they are parasitized by the tachinid *Bucentes geniculata* (Deg.) (Rennie and Sutherland, 1920).

At North East Margaree it was observed that old hay sod was rather thoroughly invaded by hawkweeds, *Hieracium* spp. A similar situation exists in Digby County, N.S., in areas heavily infested with the European wireworm *Agriotes sputator* (L.). Apparently these soil insects, by feeding on the roots, thin the stand of grass and thus permit the weeds to thrive.

Good control of the larvae in lawns, where they were causing brown, dead areas, was obtained by the manager of a hotel in North East Margaree by spraying with aldrin and by the gardener of St. Rita's Hospital, Sydney, by broadcasting paris green in bran bait.

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(Received January 31, 1957)

THE RUNGE PRESS LIMITED, OTTAWA
Mailed: Tuesday, July 16, 1957